"NEWNES BUILDING PRACTICE" SERIES · VOLUME 4

CONCRETE WORK

DEALING WITH PLAIN AND REINFORCED CONCRETE CONSTRUCTION, CONCRETE ROADS, AND ROAD REPAIRS

Prepared by a Staff of Technical Experts under the direction of

E. MOLLOY

WITH ONE HUNDRED AND TWENTY-EIGHT ILLUSTRATIONS

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PREFACE

HITHERTO concrete has been made by the mixing of specified volumes of cement and aggregates with a sufficiency of water to form a plastic mass. The architect has relied on such arbitrary proportions as 1 : 2 : 4, and, if advanced in his ideas, on a slump test ; the clerk of works, if keen on concrete, has insisted on clean aggregates ; the builder has put as little cement into his batches as he possibly could ; whilst the labourer, faced with the task of placing the resulting product, has been biased in favour of adding as much water as would give him an easily handled mix, short of reducing the whole to a liquid.

In spite of these varying practices, concrete is coming more and more into use, with the result that there is a movement in favour of bringing into its manufacture and use stricter methods for maintaining quality and uniformity.

In the first chapter, consideration is given to the materials of which concrete is made, the methods of mixing them and of placing the resulting mix. Special attention is given to the subject of overcoming the faults common in mixing : the commonest fault being the use of too much water, the next, careless measurement of aggregates, and the last, the use of too great an amount of cement, this being necessary to disguise scamped turning of the material.

The second chapter deals with steel reinforcement, why and how it is used, and the practical methods of cutting, bending, assembling, and placing the steel rods.

The third chapter is concerned with the practical applications of concrete, plain and reinforced, in foundations, walls, floors, and roofs. Attention is given in this chapter to the methods of applying reinforced-concrete units in place of traditional materials, such as timber and steel, in the construction of houses. In view of the shortage of timber at the time this book is being published—a shortage that may continue for some time to come—the substitution of precast sections having a strength virtually equal to a timber section of the same size for joists, rafters, purlins, etc., is of importance, and may assume a permanent feature of building work.

Chapter IV is devoted to formwork for concrete buildings, its construction and erection.

The chapter on Precast Work includes details of many examples of this class of work : bricks and slabs, window heads and sills, doorways, steps, cornices, etc., with full instructions for making them. Similarly in Chapter VI practical instructions are given as to making concrete paths, edging, and garden steps.

An important chapter is that on the construction of concrete roads and road repairs which is dealt with in detail. The final chapter deals with the surface treatment required for concrete walls and floors.

We have to thank the Cement and Concrete Association for their assistance in providing information and illustrations pertaining to modern concrete practice.

We present this compilation of information in the belief that it will prove of real benefit to architects, builders, foremen, and to all those engaged in the supervision and carrying out of concrete work.

E. M.

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CONCRETE WORK

Chapter I

CONCRETE MATERIALS, MIXING AND PLACING

IN concrete work, perhaps more than any other form of construction, it is important to realise the responsibility which rests on the practical man in charge of the job. Modern research has shown that, with proper control and supervision, concrete can be produced with safe working stresses much in excess of those in general use to-day. This can only be done, however, by training craftsmen in concrete, having a thorough understanding of the properties of the material, and taking a pride and interest in their work. The proposed Code of Practice drawn up by the Reinforced-concrete Structures Committee of the Building Research Board takes this into consideration by allowing for three grades of concrete : ordinary grade, high grade for work with constant supervision, and special grade, in which the concrete may be stressed in proportion to the strength actually obtained, and in which the standard is maintained by means of constant tests. If this code is generally adopted, there will be a definite incentive to produce better-quality work.

To the practical man, it is necessary to point out that the strength of concrete depends, not only upon the quality of cement and aggregates, but also upon the quantity of water used in mixing, the thoroughness of mixing, and the care taken in placing and consolidating in position. In fact, using the same materials, it is possible for the concrete to vary in strength by as much as 50 per cent. when made by different gangs.

MATERIALS

It is obviously impossible to make good concrete unless sound materials are used. Not only must the materials be sound when they are delivered on to the site, but proper care must be taken to see that no deterioration takes place before they are used in the work. The quality of steel and cement is usually specified by the engineer or architect, but the quality of sand, coarse aggregate, and shuttering is often left to the clerk of works or the contractor. Samples of sand and coarse aggregate should be submitted for approval before ordering in bulk, and works test certificates should be obtained for all consignments of cement and steel. These are usually called for by the engineer responsible for the work. Cement should be stored in a weatherproof shed with raised floor, and should not be removed until required for mixing. Steel reinforcement should be

stored off the ground, and put under cover if left on the site for any considerable length of time.

Cement

It is usual to specify that Portland cement shall be in accordance with the British standard specification, but the manufacture of cement has so improved in recent years that the quality produced by most reliable manufacturers—in this country, at any rate—is far in excess of that demanded by the British standard specification. The following table shows the increase in strength called for by the various issues of the British standard specification, and also the strength it is possible to obtain with a reasonably good cement to-day.

TABLE 1

INCREASE IN STRENGTH CALLED FOR BY THE VARIOUS ISSUES OF THE BRITISH STANDARD SPECIFICATION

	Tensile Strength (lb./sq. in.)					*Residue on 180-mesh Sieve*
	Neat		*3 : 1 Mortar*			
	7 days	*28 days*	*3 days*	*7 days*	*28 days*	*per cent.*
B.S.S., 1904	400	500	—	120	225	22·5
,, 1907	400	500	—	150	250	18
,, 1910	400	500	—	150	250	18
,, 1915	450	538	—	200	250	14
,, 1920	450	538	—	200	250	14
,, 1925	600	—	—	325	356	10
,, 1931	—	—	300	375	—	10
Good modern cement	900	1,150	450	650	800	5

Cement soon deteriorates if left exposed, and it is therefore advisable to obtain it fresh from the works as required ; old or lumpy cement should never be used for good-class work.

Rapid-hardening cement is Portland cement subjected to extra-fine grinding, which does not affect the setting time to any great extent, but accelerates the hardening process.

Aluminous cement has a different chemical composition from Portland cement, and the two should never be mixed.

Sand

Sand for reinforced-concrete work should be clean, well graded from ¼ in. diameter down to dust, and consist of hard, non-porous particles.

The most common sources of supply are by dredging from rivers, digging from pits, and artificially producing by crushing rock and screen-

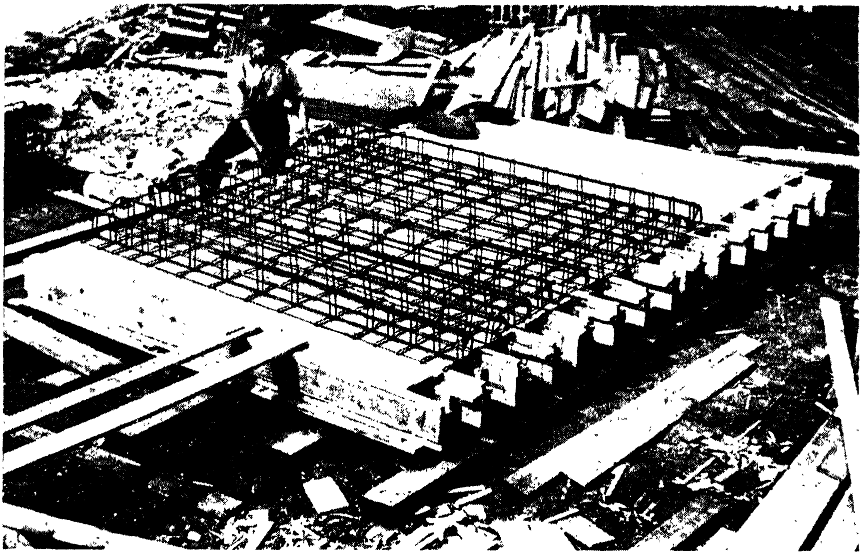


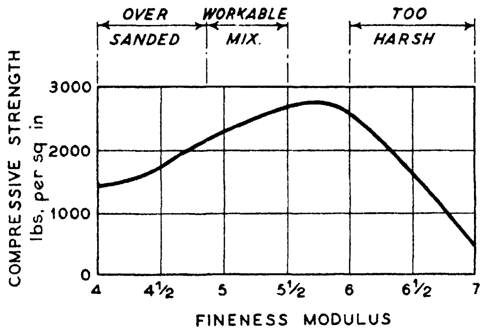
Fig. 1.—Precast floor units in process of manufacture for the Walthamstow Stadium

(*Reinforced-concrete engineers : John Liversedge & Co.*)

ing out the fine material. This last method provides a very satisfactory sand, providing the rock is of good quality. Pit sand varies considerably in quality, and should always be subjected to careful examination and tests. River sand is more reliable, but should always be tested if there is any doubt as to quality. Impurities may consist of clay, organic matter, chalk, lime, or coal, etc., and of these, the first two are the most common sources of trouble.

To test for clay, mix a fair sample of sand with about two volumes of water in a glass jar, well stir, and allow to settle. The sand grains will rapidly fall to the bottom, leaving the clay in suspension. Allow to stand until the liquid has cleared, when the clay will have been deposited as a thin layer on top of the sand. If the silt exceeds 5 per cent., the sand should not be used.

To test for organic matter, take one volume of sand and mix thoroughly with two volumes of a 3 per cent. solution of caustic soda in a glass vessel. Allow to stand for 24 hours, when the presence of organic matter will be indicated by a brown discoloration of the solution. If this is darker than straw colour, then the sand should not be used without further analysis. The effect of organic matter is to retard the setting of the concrete, with possible disintegration. In all cases where there is any doubt as to the quality of either sand or coarse aggregate, samples



From "Concrete Year Book"

Fig. 2.—Compressive strength of Concrete

should be submitted for expert examination in a laboratory.

Coarse Aggregate

The essential properties of any aggregate for reinforced-concrete work are that it shall be clean, hard, suitably graded, weather-resisting, and inert in the presence of water and cement. For ordinary work, gravel or crushed stone is generally used, and in this country, at any rate, good local materials are usually available, and economic considerations will determine to some extent the material to be used. The particles should be round or cubical in shape, and well graded between ¼ in. and ¾ in. in size, except in special cases where a larger or smaller aggregate may be called for.

As with sand, it is important that coarse aggregate should be free from clay, organic matter, or chemical impurities. Sulphur is especially harmful, and for this reason coke breeze or clinker should not be used. Furnace slag is also liable to contain injurious chemicals, and should only be used after satisfactory tests have been made. Broken bricks make quite a satisfactory aggregate providing the bricks are of good quality, well burnt, and free from lime mortar, plaster, or building debris.

The properties of the resultant concrete will depend to a large extent upon the quality of the aggregate. Thus, for watertight work, the particles should be smooth and close-grained; for wearing surfaces, they should be hard and resist abrasion; and for fireproof work, they should be stable under heat.

Grading and Proportioning Aggregates

A good deal of investigation has been carried out on the grading of aggregates with a view to producing dense, hard concrete with a minimum of cement. As the cost of Portland cement is usually five or six times the cost of aggregates per ton, it will be seen that any saving in cement is of economic importance.

The ideal aggregate is one in which the particles vary uniformly in size from dust to the maximum. In order to give a standard measurement of grading, the following method has been evolved and is largely advocated in the United States. A representative sample of the material is passed successively through a series of sieves having 100, 50, 30, 16, 8, 4, 2⅔, 1⅓, and ⅔ openings to the linear inch. The weight of material

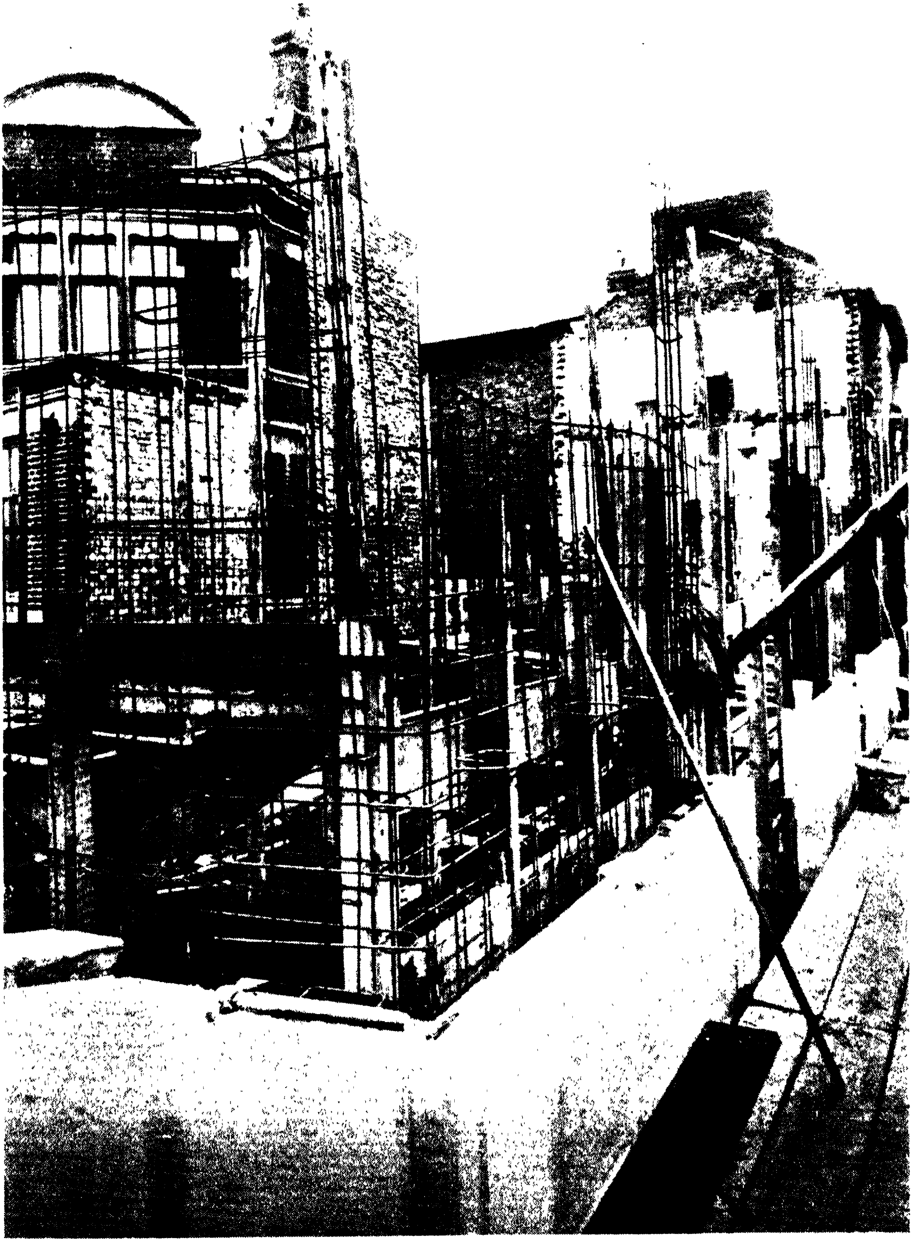


Fig. 3.—Reinforcement for National Provincial Bank Building, Ealing
(*Reinforced-concrete engineers : John Liversedge & Co.*)

retained on each sieve is measured and put down as a percentage of the total weight, thus :

Retained on	100 sieve	..	97 per cent.
,, ,,	50 ,,	..	95 ,, ,,
,, ,,	30 ,,	..	90 ,, ,,
,, ,,	16 ,,	..	80 ,, ,,
,, ,,	8 ,,	..	75 ,, ,,
,, ,,	4 ,,	..	65 ,, ,,
,, ,,	$2\frac{2}{3}$,,	..	40 ,, ,,
,, ,,	$1\frac{1}{3}$,,	..	20 ,, ,,
,, ,,	$\frac{2}{3}$,,	..	0 ,, ,,
		Total	562

$$\text{Fineness Modulus} = \frac{562}{100} = 5{\cdot}62$$

Experiments show that the compressive strength of the concrete varies with the fineness modulus somewhat as shown in the diagram (Fig. 2) for any particular mix.

If the fineness moduli of the sand and coarse aggregate taken separately are A and B respectively, then the proportion of sand R necessary to give any required fineness modulus M in a mixture of the two is given by the ratio :

$$R = \frac{A - M}{A - B}$$

This method will usually give a smaller percentage of sand than is generally used, and it is safer to have too much sand rather than too little.

In this country, the general practice is to specify that the concrete shall be mixed with certain proportions of cement, sand (dust to $\frac{1}{4}$ in.), and coarse aggregate ($\frac{1}{4}$ in. and over). To obtain a dense concrete, it is necessary for the cement to fill the voids in the sand, and for the cement and sand mortar to fill the voids in the coarse aggregate. As the voids do not usually exceed 40 per cent. in either case, it will be seen that the standard 1 : 2 : 4 mix fulfils this condition with a reasonable margin of safety. With properly graded materials, the voids may be as low as 30 per cent., and a corresponding saving in cement could, therefore, be made. It is usual to specify that not more than 10 per cent. of the sand shall pass a 180-mesh sieve, and not more than 25 per cent. shall pass a 50-mesh sieve.

Water

The water for concrete should be clear and reasonably free from chemical impurities. Sea-water does not appear to have much effect upon the strength of the concrete, but is liable to cause efflorescence.

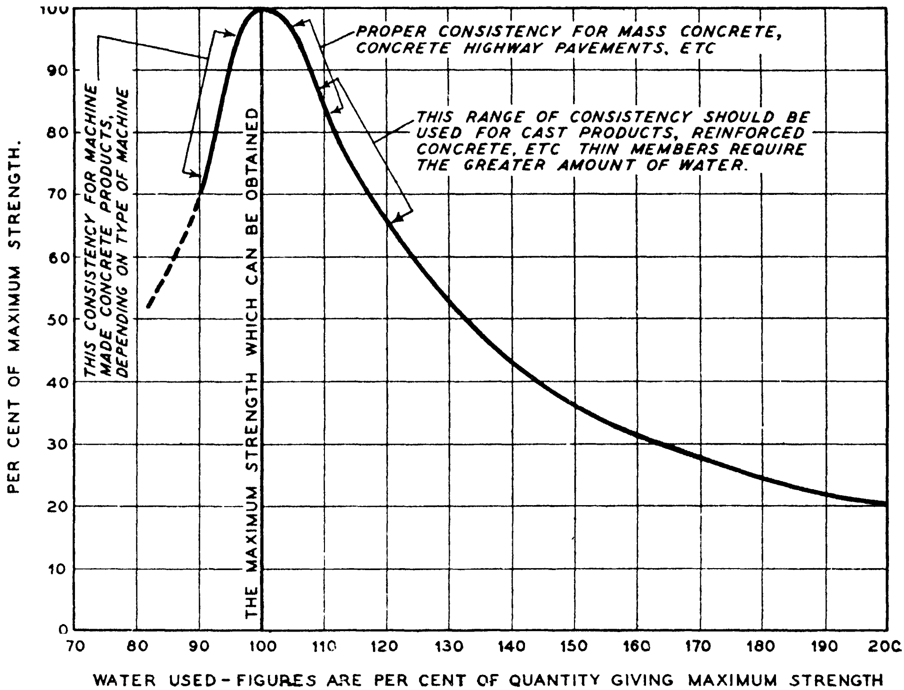


Fig. 4.—Water content strength curve

Note 30 per cent. excess of water reduces the strength of the concrete to one-half.

Wherever possible, it is advisable to use fresh water from the town supply.

The quantity of water used in mixing is most important, and several factors must be taken into consideration in determining the quantity to be used. The natural tendency is to use too much. This results in a sloppy mix, which is easy to work round the steelwork but which does not give a sound concrete.

The diagram (Fig. 4) gives some idea of the effect of water content on the strength of the concrete. From this, it will be seen that the strength falls rapidly if either too little or too much water is used.

An attempt was made in America to standardise the amount of water to be used by means of a fixed cement-water ratio. The specification would allow, say, 5 gal. of water to 1 cwt. cement, and the contractor was allowed to add as much aggregate as he wished in order to give a workable mix. This method is not by any means foolproof, and has not been adopted in this country.

A more reasonable method is to allow 28 per cent. of the weight of cement plus 4 per cent. of the weight of the aggregates, making due

allowance for any water which may be contained in the sand. This gives results as follows :

TABLE II

WATER USED FOR VARIOUS MIXES

Mix	*Weight of Materials (Lb.)*			*Volume of Materials (Cu. Ft.)*			*Water (Lb. per 112-lb. Bag of Cement)*			*Water per Bag of Cement (Gal.)*	*Water per Cu.Yd. of Sand and Ballast (Gal.)*
	Cement	*Sand*	*Ballast*	*Cement*	*Sand*	*Ballast*	*28 per cent. Cement*	*4 per cent. Sand and Ballast*	*Total*		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1 : 4 : 8	112	448	896	$1\frac{1}{4}$	5	10	31	54	85	8·5	15·3
1 : 3 : 6	112	336	672	$1\frac{1}{4}$	$3\frac{3}{4}$	$7\frac{1}{2}$	31	40	71	7·1	17·1
1 : 2 : 4	112	224	448	$1\frac{1}{4}$	$2\frac{1}{2}$	5	31	27	58	5·8	20·9
1 : $1\frac{1}{2}$: 3	112	168	336	$1\frac{1}{4}$	$1\frac{7}{8}$	$3\frac{3}{4}$	31	20	51	5·1	24·5
1 : 1 : 2	112	112	224	$1\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{1}{2}$	31	13	44	4·4	31·6

Controlling Water Content by the Slump Test

A good practical way of controlling the water content is by means of the slump test. A truncated, cone-shaped mould is used, 12 in. high, 8 in. diameter at the base, and 4 in. diameter at the top, and provided with handles. The mould is filled with concrete in layers of 4 in. at a time, each layer being rammed thirty times with a pointed metal rod $\frac{5}{8}$ in. diameter by 12 in. long. When the mould has been filled in this manner, it is slowly raised and the slump measured, from the top of the cone to the highest point of the concrete. The test should be carried out on a firm, level base, free from vibration. A slump of 1 in. indicates a very stiff mix, with very little excess water. For beams, columns, and walls the slump should be between 2 in. and 4 in., and for watertight work, from 4 in. to 5 in. The slump should never exceed 6 in. The amount of water required to give the necessary slump should be checked over every 2 or 3 days, as the water content in the sand and aggregate may vary, and as the slump will also be affected by any variation in the grading of the materials in different delivery batches.

Having decided upon the aggregates to be used and the proportion in which they are to be mixed—these latter being usually chosen by the architect and stated in the specification, or taken from the table of suggested mixes (Table II)—it is necessary to prepare for the actual mixing.

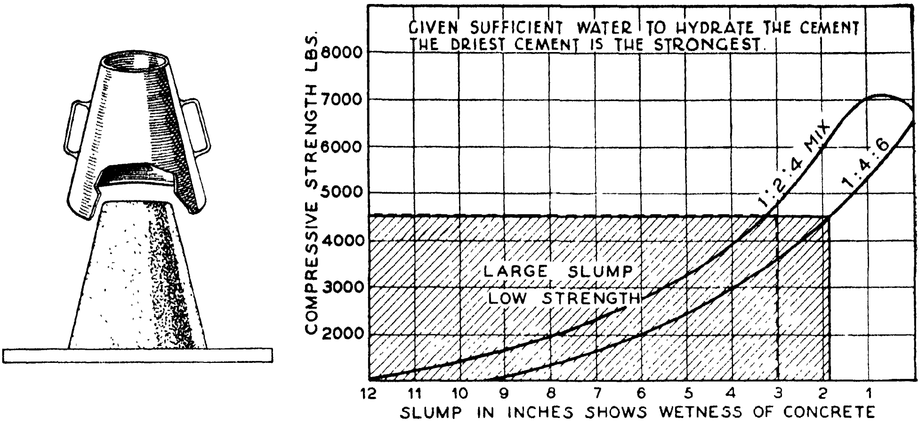


Fig. 5.—SLUMP TEST

Mixing

Concrete may be mixed either by hand or by machine. Hand mixing is quite satisfactory, providing proper precautions are taken and providing the men know their job. In order to guard against careless mixing, it is usual to specify that 25 per cent. extra cement be used for hand mixing.

Hand Mixing

If mixing is to be done by hand the first requirement is a banker preferably of wood and at least ten feet square. If any considerable quantity is to be made the banker pays for any trouble taken in construction and should consist of sound boards tightly wedged up together and securely nailed to cross pieces of 3 by 4, the nail heads being well punched down to avoid the irritating catching of the edges of the shovels.

A small banker is a poor investment, for as the heap of material is turned it inevitably runs over the edge and is wasted, or if picked up takes dirt or dust with it to the detriment of the resulting concrete.

Mild-steel plates are sometimes recommended but are heavy, and not easy to obtain in large sizes, so that they must be joined, which is difficult to do without leaving a protruding edge. Unless carefully cleaned mild-steel plates are liable to accumulate a skin of dried cement which makes them heavier than ever and is apt to flake off at inconvenient times and get into a mix.

Measuring Boxes

The next essential is good measuring boxes. These should be of wood, bottomless, and strongly made. For normal-sized mixes, one box of 1 cu. ft. capacity and one of 7 cu. ft. are the best, but where a number of men are employed the larger box may be made to hold $\frac{1}{2}$ cu. yd.

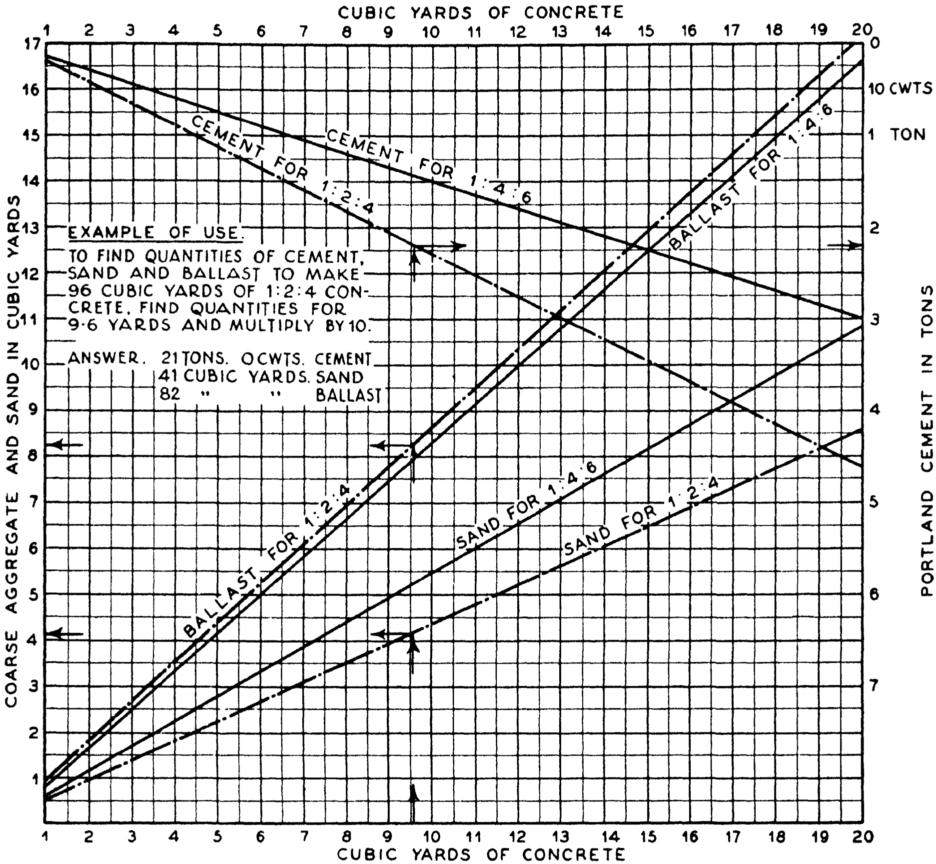


Fig. 6.—Concrete mixing chart

TABLE III

Materials to make 10 cu. yd. Concrete

Cement	*Sand*	*Ballast*	*Mix suitable for*
2 tons 13 cwt.	4¾ cu. yd.	7½ cu. yd.	Best-quality reinforced concrete, water-tight.
2 tons 3 cwt.	5 cu. yd.	8 cu. yd.	Ordinary reinforced concrete.
1 ton 15 cwt.	5¼ cu. yd.	8¼ cu. yd.	Mass concrete.
1 ton 10 cwt.	5½ cu. yd.	8½ cu. yd.	Footings, etc.

It is essential to have some means of measuring the amount accurately. Standard 2-gallon watering cans fitted with large roses are the best; they can be filled from a tank or barrel kept supplied by a hose or stand pipe.

Measuring out the Mix

Having placed the larger measuring box on the banker and rather nearer to one edge than another, fill it level with ballast or coarse aggregate as many times as are necessary to give the correct number of cubic feet, lifting the box between each filling and flattening the top surface of the pile. Repeat the operation with the sand and finally, using the smaller box, with the cement.

The Mixing Process

Commencing at the side nearest the vacant banker, transfer the whole pile to the farther side, repeating this operation three times or more if necessary to obtain an even colour throughout and piling the material in a cone.

Then and then only commence to add the water, directing it on the side of the heap which is being attacked by the shovels. After all the water is added turn again three times.

Water poured from a pail always washes the cement grout off the coarse aggregate, needing more turning to get it covered so as to avoid the presence of uncoated and non-adhering particles in the finished concrete.

Having measured the cement there should be no need for the commonly seen operation of dusting with cement to make the mix drier. It will be wet enough if the water has been measured.

Hand Mixing Large Quantities

When hand mixing very large quantities which can be shovelled directly off the banker into an excavation or pier hole, a long banker should be used, the material being dumped at one end when measured and turned over and over towards the discharge end, the men working the wet concrete changing at intervals with those working the easier dry end.

Mixing by Machine

When mixing by machine there is a great tendency to use wheelbarrows as measures, on the assumption that each barrow holds a definite 3 or 4 cu. ft. of ballast or sand. The average labourer prefers to wheel 2 cu. ft., and unless they are made to strike each load off level, measurements become mere guess-work; this, it should be noted, is as liable to favour strong and uneconomic concrete as weak and cement-saving concrete.

The greatest drawback to machines is the tendency for the dry materials to stick in the loading hopper instead of running into the drum ; care should therefore be taken to follow a regular routine. The first measure of ballast should be banked against the back and sides of the hopper, the cement deposited in a rough pile, and the remainder of the aggregates filled in on top of it so as to form a sandwich. In this condition it will run freely unless the hopper discharge lip is dented. If it is, the best remedy is a new hopper, for no satisfaction can be obtained from any mixer which needs hammering or poking.

Machine mixing reduces the human factor and gives a more reliable mix. The mixing machine should be of the batch type, and of a size suitable to the rate of progress required. It is worth while giving some thought to the layout of concreting plant in order to get the best results. The materials should always be measured, either in gauge boxes or in standard barrows, and it is an advantage to have a size of batch which requires 1- or 2-cwt. bags of cement. The materials should be mixed dry before adding the water. As previously explained, the amount of water used in mixing is most important, and should always be carefully controlled, to give the required slump and the correct quantity measured for each batch.

Using Ready-mixed Concrete

It is interesting to note, in passing, that concrete may be purchased in London ready mixed. The materials are mixed in a revolving drum on the delivery vehicle and water added as the site is approached. It is not advisable to transport fluid concrete any considerable distance, as the materials tend to segregate.

Placing and Tamping

Concrete should be placed in position as soon as possible after mixing, and always before the initial set takes place, which may be within 20 minutes, although it is usually somewhat longer and varies considerably with different batches of cement. Before commencing to place the concrete, a careful inspection should be made to see that all steel reinforcement is correctly fixed, and that the formwork is rigidly braced and strutted. All sawdust, wood, dirt, or other foreign matter must be removed, and the face of the shuttering treated with mould oil, soft soap, or any other preparation which may have been specified, although, in general, these should have been applied before the reinforcement was fixed. A check should also be made to see that all boxing or blocks for openings, bolt holes, etc., are in the correct position, as this may save considerable time and money in cutting away afterwards.

The concrete should be placed carefully in position in small quantities, and not thrown from a height or tipped in bulk. As soon as the concrete is placed, it must be well rodded into position around the reinforcing bars

and along the face of the shuttering. Failure to give adequate attention to working the concrete into position will result in porous concrete with a honeycomb surface. Column heads and junctions of beams should receive special attention. Very good results are obtained by using specially designed vibrators working at a frequency of from 6,000 to 12,000 vibrations per minute. Properly applied, these result in a very dense concrete with a good working face, and the water content may often be reduced. Over-vibration should be avoided, as it tends to cause segregation of the materials.

It is not advisable to mix or place concrete during frosty weather except for urgent work, when special precautions must be taken. The sand and gravel should be heated and the work well protected. The greatest damage is done by frost just after the final set has taken place, and concrete thus frozen is completely disintegrated. Rapid-hardening and aluminous cements are of advantage in cold weather, as they generate more heat than slow-setting cements, and this helps to raise the temperature of the concrete during the hardening process.

When placing direct on soil, the latter should be wetted or the concrete laid on sheets of special paper sold for the purpose. When placing in moulds, the latter should be well wetted to prevent stealing of the water from the concrete and the greatest care should be taken to remove sawdust or chips.

If wooden plugs are left in to form holes, it is well to remember that concrete contracts as it sets and a wrapping of paper will often save considerable work in withdrawal.

When placing concrete on concrete which is already set, the whole surface of the latter should be carefully picked, rough washed free from dust, and well wetted. A layer of cement grout having been poured on, it will bond perfectly with the succeeding deposits.

The greatest enemy of good joints is the laitance or milkiness which is often present due to the use of too much cement and water. It is composed of useless matter in the cement and has no strength. For this reason it should be completely removed.

Floors

In floors and the like, thorough ramming of the concrete will allow of using a really dry and therefore strong mix, and the practice has everything to commend it despite the fact that it makes floating difficult if done in the upper layers.

In floor work it is necessary to obtain a hard top surface free from cracks or blemishes. This is easily done by covering the concrete with sacking or sawdust kept damp for as long a period as possible. The slowness of drying results in a curing of the surface which has the most beneficial results, and it is a pity that it is not more frequently practised.

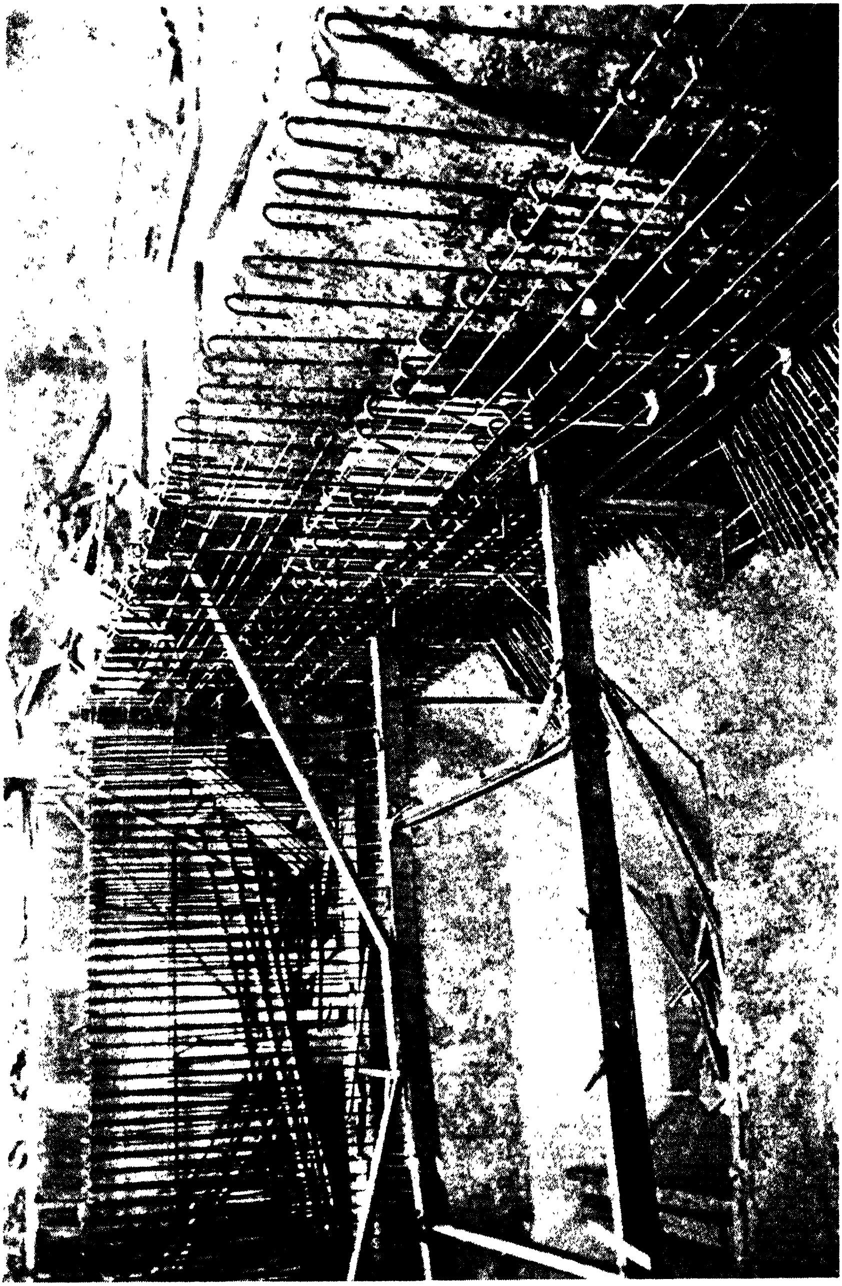


Fig. 7.—Reinforcement for Detritus Pits, Glenboig Sewage Works. (*Reinforced-concrete engineers : John Liversedge & Co.*)

Construction Joints

As a general rule, it is advisable to carry out concreting as continuously as possible, in order to reduce the number of construction joints to a minimum. Where construction joints are unavoidable, the positions should be carefully determined beforehand. In beams and slabs, the concrete should be stopped at a vertical face where the shear is low, either over a support or within the middle third, preferably the latter. Beams are usually concreted before the slab, and this enables the number of joints in beams to be reduced to a minimum. Horizontal joints in walls should be made straight and true to level, as uneven joints can be most unsightly. A good tip is to fix a small batten at the top of the shutter, as shown in Fig. 8.

When work has to be resumed on a surface that has hardened, every care should be taken to make a sound joint. The old surface should be well roughened and all laitance removed, after which it should be swept clean, thoroughly wetted, and covered with a layer of mortar composed of equal parts of cement and sand, well worked in. Special precautions should be taken in watertight work.

Expansion Joints

Concrete, like most other materials, expands when heated and contracts on cooling, and it is necessary to take this into consideration if temperature cracks are to be avoided. When heated through 70° F., which range of temperature is quite common in this country, a length of 100 ft. of concrete will expand about half an inch. When joints can easily be provided, as in slabs on solid ground, the concrete should be cast in bays not exceeding 50 ft. in length, and the joints filled with 1-in. thickness of bitumen or cork. In a complete reinforced-concrete structure, it is usual to allow for expansion joints about 150 ft. apart, and in composite structures the bearing surfaces should be made as frictionless as possible to allow freedom of movement between the different materials.

Curing

Concrete cannot develop its full strength unless kept in a moist condition during the hardening process. In practice, it is advisable to keep it moist for at least 7 days, and to protect all exposed surfaces from wind or sun by covering with sand or sacking, moistened from time to time. At 28 days, concrete cured in water is about 12 per cent. stronger than concrete cured in air.

Steel Reinforcement

This usually consists of mild steel, in accordance with British standard specification No. 15, which specifies a breaking strength of from 28 to 33

BLOCKS USED IN MACHINERY AND EQUIPMENT VOLUME

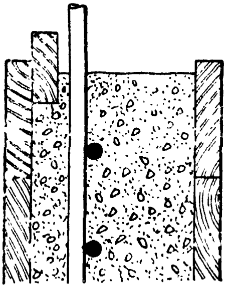


Fig. 8.—A SMALL BATTEN FIXED AT TOP OF SHUTTER ENSURES A STRAIGHT JOINT

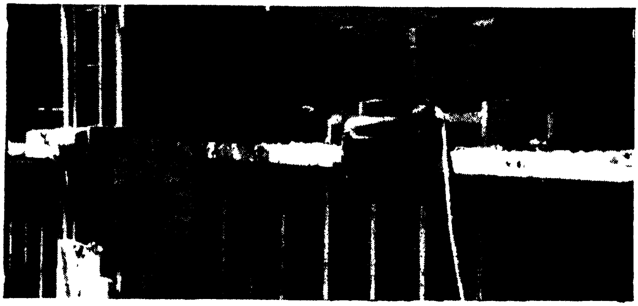


Fig. 9.—AN ELECTRIC VIBRATOR. (*By courtesy of E. P. Allam & Co. Ltd.*)

tons per square inch. In addition, there are various special bars and fabrics on the market. All steel reinforcement should be carefully checked over upon arrival at the site, and stored for easy access. The steel should be clean when placed in the work, free from mill scale, loose rust, oil or grease, or other deleterious matter. Care should be taken to see that the bars are bent accurately to shape, or otherwise difficulty will be experienced in fixing. Steel-bending may be done either at the works or on the site, but, in either case, the bars should be bent cold in a suitable bending machine. As soon as bent, the steel should be labelled for easy reference when fixing. It is, of course, most important that the steel reinforcement be accurately and rigidly fixed in position, the bars being wired together with soft-annealed binding wire, and the whole of the steel should be checked over in position before concreting commences.

Shuttering and Formwork

The construction and erection of formwork comprises a large percentage of the cost of reinforced concrete, usually between 25 per cent. and 40 per cent., and it is often worth while preparing special designs and drawings for the use of the foreman on the site, especially in large and complicated works. For ordinary beam and slab construction, the shuttering may be safely left to an experienced foreman. It is advisable to have all timbering of substantial size, and all formwork should be well strutted and braced so as to prevent any excessive deflection when carrying the dead weight of the concrete. It is false economy to use thin sheeting, which may bulge under the pressure of the concrete : such mistakes are expensive to rectify. To prevent loss of grout, all joints must be tight and, as a general rule, wrought timber should be used for all exposed surfaces of concrete. As previously mentioned, the shuttering should be cleaned and treated with soft soap or mould oil before concreting commences. For further details regarding formwork, see Chapter IV.

Test Cubes

It is always advisable to keep a check on the quality of the concrete by means of test cubes. These should be cast in steel moulds with a 6-in. side, which should be filled with concrete from an actual batch and, as far as possible, the conditions of curing should be similar to those in the actual job. These test pieces will have to be sent to a testing laboratory for crushing at 7 days, 28 days, and 3 months. The 28-day test is, perhaps, the most valuable, as it is usual to allow this period of time before putting any considerable load on the structure. The results of these tests should give a strength at 28 days of at least four times the working strength when ordinary Portland cement is used.

Light-weight Concrete

The weight of concrete may be reduced by using light-weight aggregates. Such aggregates may consist of materials used in the state in which they occur naturally, such as pumice, or of artificial light-weight materials.

Light-weight concrete forms an excellent insulation against heat and sound, has a satisfactory fire resistance, and is easy to cut with bricklayer's tools.

The approximate densities of various light-weight concretes are given in the following table :

	Pumice Concrete		*Clinker Concrete*		*Foamed Slag Concrete*		*Ordinary Concrete*	
Mix (by vol.)	1 : 6	1 : 10	1 : 6	1 : 10	1 : 6	1 : 10	1 : 6	1 : 10
Approx. density in lb./cu. ft.	48	41	105	95	80	69	147	151

Precast slabs of light-weight concrete may shrink on drying if erected in a wet condition.

Coloured Portland Cements

Following the introduction of British coloured and white Portland cements, great strides have been made towards the production of concrete with a highly artistic appearance.

Ordinary Portland cement can be coloured by the addition of suitable pigments (usually mineral oxides). Where dark colours such as brown, red, black, etc., are required, they are made by mixing the appropriate pigment with ordinary grey cement, but, for all light colours, white Portland cement should be used as the base.

It must be appreciated that more consistent colouring is likely to be obtained by the use of cements into which the colour has been incorporated during process of manufacture. The table below is given only as a

guide when the individual desires to do the mixing and does not object to some slight variation in tone.

Colour	*Pigment*
Buff and Yellow	Yellow ochre.
Brown	Brown oxide of iron.
Green	Green oxide of chromium.
Pink or Red	Red oxide of iron.
Black	Manganese black.

The weight of pigment used should not exceed 10 per cent. of the weight of the cement, otherwise the strength of the mortar will be reduced.

Too much emphasis cannot be laid on the desirability of ensuring that an intimate mix is made with the cement and pigment. A good method is to mix the cement and pigment together first and pass this mixture through a sieve, not larger than No. 10 size, three times in the dry state.

To ensure that a uniform colour be maintained it is necessary to keep accurate records of the amount of pigment, water, and other materials, added to each batch of cement. It is advisable to make a small sample of the coloured concrete in order that the exact shade, when dry, may be seen.

MEMORANDA RELATING TO MATERIALS

One ton of Portland cement = 20 bags of 1 cwt. (112 lb.) net each.

Rapid-hardening cement is also supplied in 1-cwt. bags.

The Royal Institute of British Architects advises the adoption of 90 lb. as the basis of comparison in converting cement from cu. ft. to lb. for proportioning concrete. This has also been adopted as the standard by the London County Council in their Regulations for reinforced-concrete construction in London.

TABLE IV

SIZE OF SQUARE-GAUGE BOX TO HOLD 1 CU. FT. OF CEMENT

Depth of Box (inches)	=	7	8	9	10	11	12	13	14
Side of Square (inches)	=	$15\frac{3}{4}$	$14\frac{3}{4}$	$13\frac{7}{8}$	$13\frac{1}{8}$	$12\frac{1}{2}$	12	$11\frac{1}{2}$	$11\frac{1}{8}$

1 cu. ft. = 0·037 cu. yd. = 1,728 cu. in.
1 cu. yd. = 27 cu. ft. = 46,656 cu. in.
1 ton = 20 cwt. = 2,240 lb.

Water

1 cu. ft. of fresh water weighs 62·4 lb. = 6·24 gallons = 0·037 cu. yd.
1 gallon of water = 10 lb. = 0·16 cu. ft. = 277·46 cu. in.
1 cu. ft. of salt water weighs 64 lb. = 6·4 gallons.

Concrete

Average weight of 1 : 2 : 4 concrete : Coke breeze as coarse material, 100 lb. per cu. ft. ; clinker, 110 lb. per cu. ft. ; brick, 125 lb. per cu. ft. ; limestone, 140 lb. per cu. ft. ; shingle as coarse material, 150 lb. per cu. ft. (The three latter materials are to be preferred.)

Sand and Aggregate

1 ton = 21 cu. ft. river sand = 22 cu. ft. pit sand = 22 cu. ft. ballast = 23 cu. ft. coarse gravel = 24 cu. ft. clean shingle.

Quantity of Concrete

1 cu. ft. of loose Portland cement will make about :

$3\frac{3}{4}$ cu. ft. of concrete mixed	1 : 2 : 3
$4\frac{3}{4}$,, ,, ,,	1 : $2\frac{1}{2}$: 4
$5\frac{3}{4}$,, ,, ,,	1 : $3\frac{1}{4}$: 5
$6\frac{3}{4}$,, ,, ,,	1 : 4 : 6

TABLE V

MATERIALS REQUIRED PER CU. YD. OF CONCRETE

Based on Absolute Volume method, with cement weighing 90 lb. per cu. ft., sand 84 lb. per cu. ft. when damped and bulked 30 per cent., gravel or shingle 109 lb. per cu. ft., and broken stone 90 lb. per cu. ft.

Mix by volume	*Type of Coarse Aggregate*	*Cement*	*Sand (Damp)*		*Coarse Aggregate*	
		lb.	*cu. yd.*	*tons*	*cu. yd.*	*tons*
A	Shingle	335	0·54	0·55	0·83	1·09
1 : 4 : 6	Broken stone ..	370	0·59	0·60	0·91	0·99
B	Shingle	392	0·52	0·53	0·81	1·06
1 : $3\frac{1}{4}$: 5	Broken stone ..	432	0·58	0·59	0·89	0·96
C	Shingle	481	0·51	0·52	0·79	1·04
1 : $2\frac{1}{2}$: 4	Broken Stone ..	524	0·56	0·57	0·86	0·93
D	Shingle	596	0·48	0·49	0·74	0·97
1 : 2 : 3	Broken stone ..	653	0·52	0·53	0·80	0·87
E	Shingle	813	0·43	0·44	0·67	0·88
1 : $1\frac{1}{4}$: 2	Broken stone ..	880	0·47	0·48	0·72	0·78

Example : Find the quantities of Portland cement, sand, and broken stone required for a foundation 30 ft. long by 10 ft. wide by 3 ft. thick, using Mix A.

The volume of the concrete required is :

$$\frac{30}{3} \times \frac{10}{3} \times \frac{3}{3} = 33\tfrac{1}{3} \text{ cu. yd.}$$

The amount of cement required is 370 lb. $\times$ $33\frac{1}{3}$ = 12,333 lb. = 110 cwt., or $5\frac{1}{2}$ tons.

The amount of sand required is 0·59 $\times$ $33\frac{1}{3}$ cu. yd. = $19\frac{3}{4}$ cu. yd., or 0·60 $\times$ $33\frac{1}{3}$ = 20 tons.

The amount of broken stone required is 0·91 $\times$ $33\frac{1}{3}$ cu. yd. = $30\frac{1}{3}$ cu. yd., or 0·99 $\times$ $33\frac{1}{3}$ = 33 tons.

Chapter II

STEEL REINFORCEMENT, BENDING AND FIXING

ALTHOUGH the design of reinforced-concrete buildings is the province of the architect, the application of the materials used in their construction is the province of the builder, and if he is to carry out his work intelligently he must have some knowledge of the principles underlying the combination of steel and concrete.

Concrete is normally used for its ability to resist compression, that is, crushing loads, and according to its quality and age will withstand up to 6,000 or 7,000 lb. per square inch. Though strong in compression, concrete is extremely weak in tension, such tensional strength as it has being readily destroyed by a sudden load. In addition, when setting, it

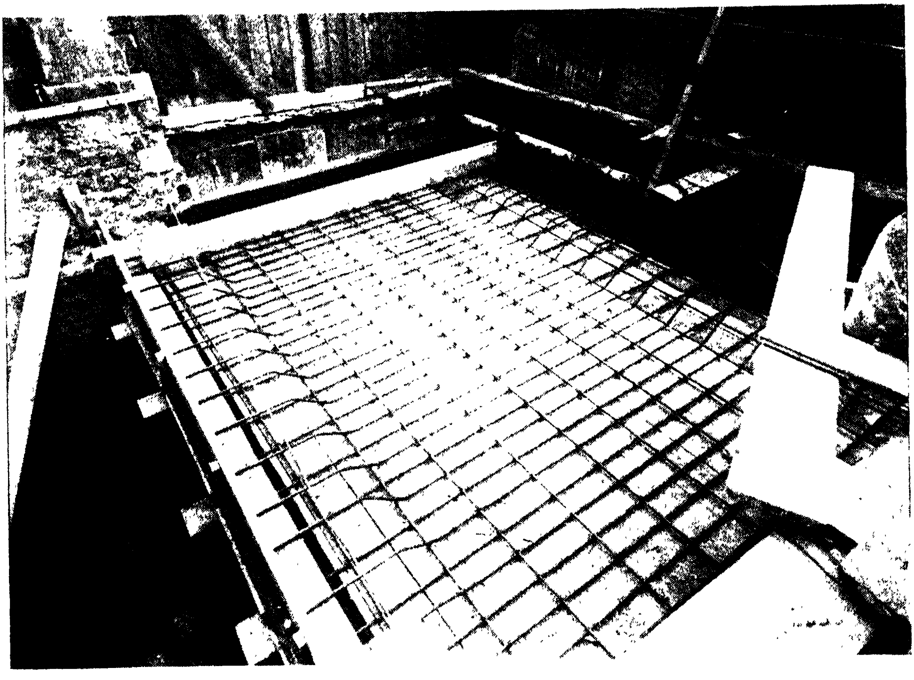


Fig. 1.—FOR REINFORCED-CONCRETE FORECOURT OVER BASEMENT
Reinforcement bars in position ready for the concrete.

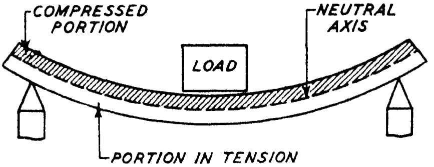


Fig. 2.—Timber beam under load

contracts, this leading to interpenetration by hair cracks which destroy the cohesion of its parts.

Reinforcement Used to Strengthen Concrete in Tension

A timber beam supported at its ends and loaded at the centre will bend, and if the timber be of a flexible character, and the load severe, will attain some such shape as shown in Fig. 2.

The upper surface of the beam, being on the inner and shorter side of the curve, is obviously shortened and compressed, whilst the lower side is similarly lengthened. Some portion near the centre of its depth is neither lengthened nor shortened, thus being neither in compression nor in tension.

This portion is usually considered to be a plane surface, and we can imagine the beam to be built up of a very large number of thin boards with the upper ones compressed along their length, the centre one unaltered, and the lower ones lengthened.

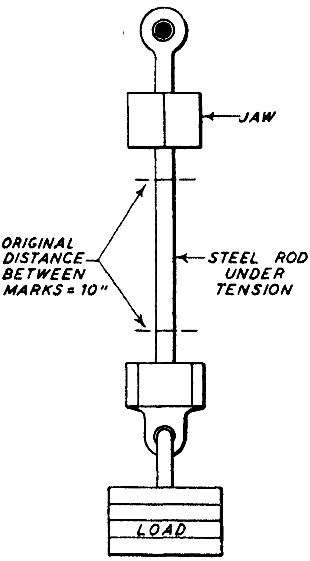


Fig. 3.—What happens to steel rod under tension

The rod will stretch, the amount being measurable by checking distance between two marks, as shown.

Were concrete used instead of timber for the construction of the beam, although the bending might not be apparent to the eye it would be measurable; the same conditions would obtain, and the lower parts would be in tension whilst the upper parts would be compressed.

Concrete being weak in tension, it is the object of reinforcement to strengthen the concrete where it is in tension, leaving it to care for the compression loads unaided. This, as we have seen, it is quite well able to do.

Why Steel Rods are Used for Reinforcement

The basic fact which makes it possible to combine steel and concrete is that the latter contracts on setting in air. If a steel rod be embedded in a mass of wet concrete it will be found that considerable force is necessary to withdraw it when the concrete is set. If a steel plate be placed on wet concrete, however, although it will resist removal when the concrete is set, it can be knocked off by a sharp blow. In the first case the concrete grips the steel, whilst in the second it only

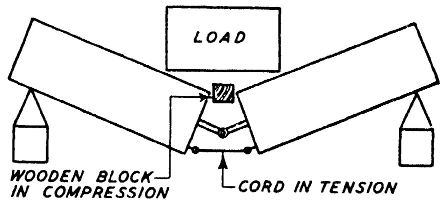


Fig. 4.—SHOWING PARTS OF BEAM UNDER TENSION AND COMPRESSION

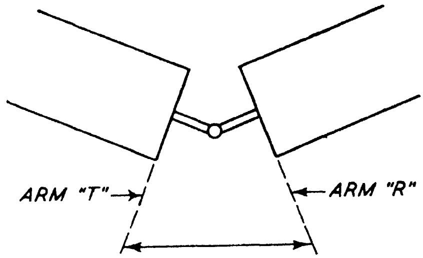


Fig. 5.—THE LOWER THE RODS THE STRONGER THE BEAM

adheres. The grip depends upon the quality of the concrete ; upon whether it has been well or badly rammed around the rod ; upon the condition of the surface of the rod, as to whether it be rough or smooth. A polished rod is less gripped than one of commercial mild steel, with its rough and lightly rust-filmed surface, whilst an oily rod is lightly held.

From time to time specially shaped bars have been introduced carrying indentations, raised ribs, or projections of one kind or another, with the object of increasing the grip, but as the grip must depend upon the strength of the concrete these bars do not achieve their purpose if set near the soffits of beams with perhaps a bare inch of cover. The actual grip or, as it is usually called, adhesion of mild steel in concrete is around 250 lb. per square inch of surface, but added security is obtained by hooking the ends of the rods in a semicircle of about four rod diameters, or by splitting the ends of the rods for a few inches and opening into a fishtail.

Steel Rods must be Placed Low in Beam

We must now consider what happens to steel when it is called upon to bear a tensional load or pull. If a rod of, say, $\frac{1}{2}$ in. in diameter be gripped in a suitable jaw, as shown in Fig. 3, and the other end loaded with a gradually increasing weight, the steel will be found to stretch, this stretch being measurable by checking the distance between two marks scratched on the rod at, say, 10 in. apart.

If from time to time the load be removed it will be found that the rod will return to its original length, just as an elastic band stretched between the finger and thumb will return to its original shape when released. At some point in the loading, however, the rod loses its power to return, and the load in pounds per square inch section of the steel at this point is known as the elastic limit.

Up to this point, dividing the load in pounds per square inch by the amount of stretch per unit of length always gives a constant result. As an example, a bar 10 in. long stretched one-hundredth of an inch has a unit stretch of $\frac{1}{1000}$. If the load were 30,000 lb., the division of load by stretch would give 30,000,000, and if the load were half the stretch

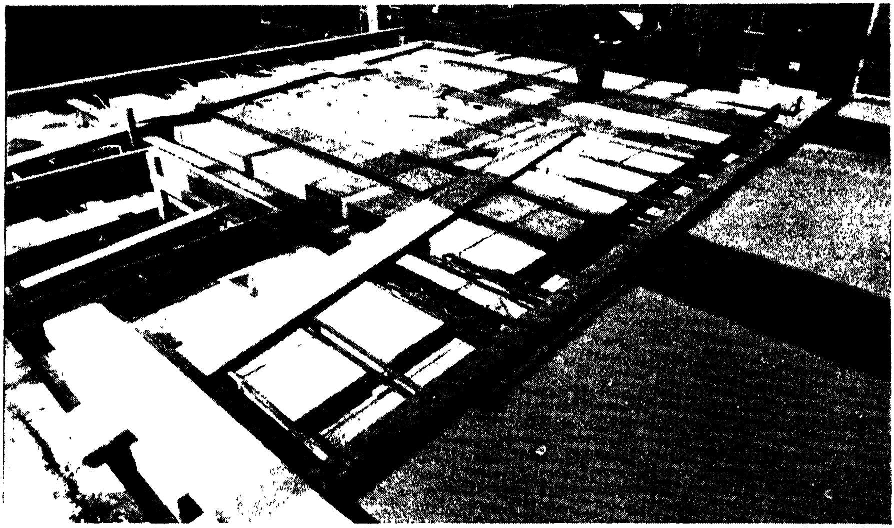


Fig. 6.—Hollow floor construction
Showing completed surface in foreground, with fixing clips for battens.

would be half, and the result of the division again 30,000,000. This figure is known as the coefficient of elasticity. With ordinary types of steel the elastic limit is reached at around 32,000 lb. per square inch, but such steel is never designed to carry more than 16,000.

Reverting to the timber beam, we can imagine it made up of two parts hinged at their centres, as in Fig. 4. The load will try to break the back of the beam at the joint, but we could prevent this by tying a cord across the gap or by jamming in a piece of wood in the position shown, when the cord would be in tension and the wood in compression.

In the enlarged view of the joint (Fig. 5) we can see that the farther down the arms R and T we fix the cord, the less pull it will have to withstand, until were the arms lengthened as shown by the dotted lines a heavy load could be sustained on the beam by a light pull.

This amounts to saying that the deeper the beam the stronger it is, or that the lower we place the steel rods the better they will be able to resist the tensional pull. Deep beams being uneconomical, as regards both material and space, the designer keeps them as shallow as possible, depending upon the correct placing of the steel by the builder.

Thickness of Covering for Reinforcement Rods

How low can the rods be placed with safety ? Although considered fireproof, concrete buildings usually contain inflammable things, and a layer of concrete must be provided as protection to the reinforcement. When steel is loaded it stretches, and if the concrete is not to spall from

the underside of beams there must be a certain thickness under the steel. In addition, concrete is permeable to damp, and uncovered or sparsely covered rods would corrode. Allowing for these three factors the usual cover in slabs is ½ in., and in beams 1 in.

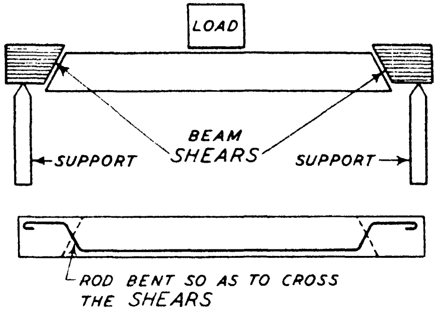


Fig. 7.—Beam reinforcement to resist shear

Strengthening Beam to Resist Shear

A very usual type of beam reinforcement consists of several rods, of which perhaps two are bent up as shown in Fig. 7.

These are intended to strengthen the beam to resist what is known as shear, which is a tendency for a portion of the beam to be pushed bodily out of the main part, as shown by the shaded portions in Fig. 7.

A man walking on a scaffold board supported at both ends bends the board farther as he gets nearer the middle. This may be stated in the following terms : the bending moment increases as the distance of the load from a support. This being so, it will be seen that the greatest stress on the steel reinforcing rods comes around the centre of the span in a normally loaded beam, and it is here that most steel is needed. A close inspection of a plate-girder railway bridge will show that there are more plates at the centre than towards the abutments, this being done for reasons of economy. In a reinforced-concrete beam, then, we can afford to bend some of the steel rods after they have done their bit near the centre, and take them diagonally upwards to cross the parts of the beam which are subjected to shear, bending them back again parallel to the top of the beam so as to give a secure anchorage.

The designer calculates the position of the steel so that it can do this work to the best advantage, and it is the builder's job, knowing the reason, to see that the drawings are strictly adhered to both in the bending and in the placing of the bars.

Why Continuous Reinforcement is Employed

In buildings of any size it frequently happens that slabs and beams are designed with steel running near the bottom, then turned up and running parallel with the upper surface and over into the next bay.

This form of reinforcement is called continuous, and the reason for its use is seen in Fig. 8, where the right-hand portion of the beam, being loaded, tends to raise the unloaded portion in the next bay.

To omit this steel on the plea that it is unnecessary is dangerous, to say the least of it, yet it is often done.

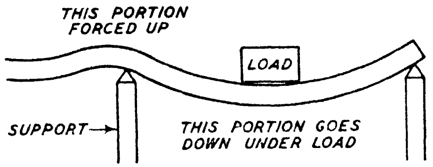


Fig. 8.—THE REASON FOR CONTINUOUS REINFORCEMENT

Reinforcing-steel

Reinforcing-steel usually consists of plain round rods, varying from ¼ in. in diameter upwards. They should be of steel with a tensile strength of between 28 and 32 tons to the square inch, and be capable of being bent cold in a half-circle around a piece of their own diameter without showing signs of cracking at the bend. The rods should be clean and free from loose rust.

Storing Rods

The best method of storing rods is in racks, which can be readily made by driving in a row of strong posts at 5-ft. centres over a length slightly less than the longest rods to be used. Bolts or short lengths of rod can then be driven slantwise into the posts to form arms, thus allowing of the segregation of the various sizes. A light roof over all will protect the rods from direct rain.

Rod-bending Bench

The bending-bench should be alongside the rack, and should be as strongly constructed as possible of good baulk timbers placed about 3 ft. 6 in. from the ground, and parallel with the storage.

As in most reinforced work there is a multiplicity of similar shaped bends, a second storage rack on the other side of the bench is an advantage, as the bends can be hung as they are finished and not thrown on the ground, where they become tangled and rusty.

Bending the Rods

The actual bending can be done either by driving steel pins into the surface of the bench in accordance with a chalked diagram, and forcing the bars around the pins by the use of a length of steam barrel slipped over the rods, or by a bending machine. The latter is in every way preferable. The bends are smoother, more rapidly made, especially if the bender be let into the bench top, so that the bending groove is flush. Using a geared bender, bars up to 1¾-in. diameter can be readily handled.

A light roof over the bench will allow of work whatever the weather, and will also avoid damage to drawings and bar schedules.

Cutting Rods

Cutting is easiest done with a bolt-cropper, care being taken to see that there is a pair of spare cutters always ready for exchange, and that the cutters are at least one size too large for their job.

The use of the oxy-acetylene torch is sometimes advocated, though

the intermittent nature of the work makes for constant lighting and consequent waste of gas. Recently a good deal of bar-cutting has been done with an electric hand-saw using carborundum discs, and where current is available this is a rapid method, particularly with bars over $\frac{3}{4}$ in.

Assembling Sections of Reinforcement Rods on Bench

Many sections of reinforcement can be inserted in beams or columns after wiring up, and these can be assembled on the bending-bench. Cradle irons of the shape shown in Fig. 9, and driven into the bench, will be found of great assistance.

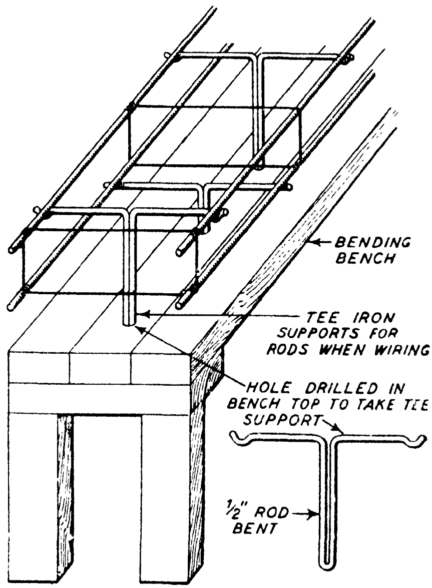


Fig. 9.—ASSEMBLING SECTION OF REINFORCEMENT ON BENCH

Cradle irons of shape shown and driven into bench will be found of great assistance.

Wiring of Joints

The wiring of the joints should be done securely, and it is unlikely that any reader will use the old method of supplying coils of soft-iron wire from which the ties are to be cut. Much of the wire is tangled and wasted, and the better method is to adopt either ready-cut lengths or one of the preformed ties sold by suppliers of concrete utilities. One such is adapted to be looped around the rods and twisted tight by a special tool, whilst another consists of springy wire clips of varying sizes to fit the rods. The former would seem to be preferable.

Placing the Rods

After the rods have been bent, the next step is to place them. The care taken in the drawing-office to ensure that the rods will fit in the forms renders placing easy if the bending has been carefully executed. If it has not, the bending should be most carefully checked, to avoid a constant repetition of the trouble right through the job.

Having brushed or washed the forms clear of odd bits of wood, sawdust, and rubbish, they should be coated with mould oil or whitewash, the former being preferable. Mould oils, when bought cheaply, consist of refuse emulsified with water. The cheaper it is the more water you obtain for your money. Oils can now be bought which can be mixed on the site with the required bulk of water,

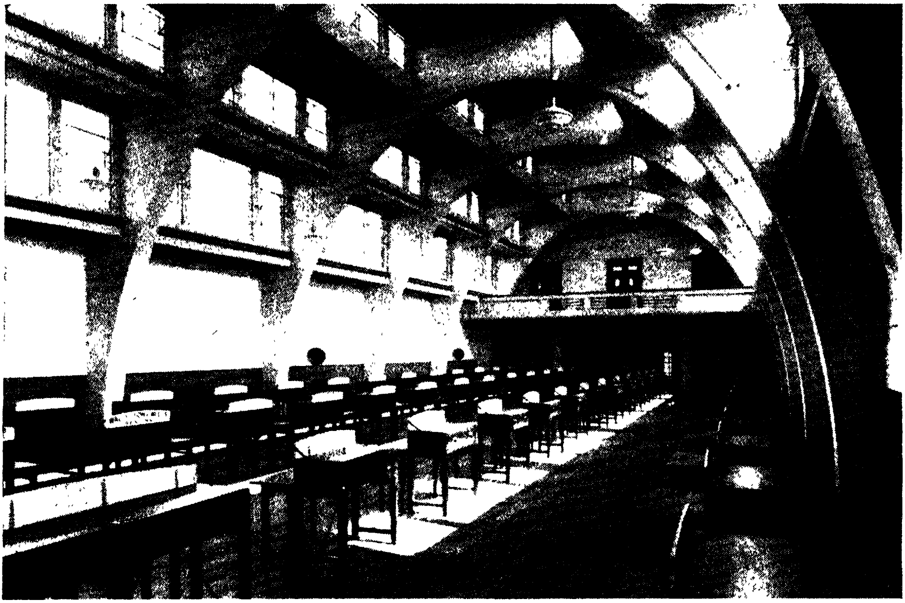


Fig. 10.—INTERIOR OF MAIN HALL, 131 FT. LONG BY 50 FT. WIDE, READING CORN EXCHANGE

Note the six reinforced-concrete elliptically shaped arch ribs or trusses at 19-ft. centres. The radii of the soffit are about 19 ft. for the middle portion and 35 ft. 6 in. at the sides. The hall is roofed on each side with a series of concrete flat roofs which rise in tiers to the highest flat, which is 36 ft. above floor level and 17 ft. wide. These flats are carried by concrete beams between the trusses. The design of the roof allows for the provision of a large amount of lighting from vertical windows. The ribs are carried on footings 6 ft. by 5 ft. At the farther end of the hall will be seen the balcony, which is 44 ft. long and 12 ft. 6 in. wide and carried on concrete cantilever beams with an overhang of 8 ft. supported on two 18-in.-square concrete columns. The front of the balcony is of reinforced concrete and wrought-iron grilles. (*Architects : Chas. Smith & Son.*)

and with a guarantee of non-separation, the cost being around three-pence per gallon.

Heavy reinforcements can be suspended by wire ties from cross-bars blocked up on the sides of the beam boxes, or rested on precast blocks of concrete which will amalgamate with the bulk. Wood blocks are not to be recommended. They show when the shuttering is removed, and are difficult to dislodge. A new form of wire bridge can now be purchased which can be placed under rods, but would seem likely to give rise to rust spots on the soffits.

VARIOUS TYPES OF REINFORCED MEMBERS

Stanchion and Column Bases and Footings

Stanchion bases, column bases, and footings are the most important and most frequently neglected portions of a building. Being in effect

reversed beams, with the stanchion forming the support and the earth pressure upwards a load about the ends, the tendency is for the concrete to break off in an upward direction, so that the steel must be placed in the bottom of the slab. The stresses being high the rods should be well hooked ; well wired together to prevent movement during filling ; and if for columns should be provided with dowel rods projecting at least twenty-four times the diameter of the rod, and securely braced in a vertical position whilst filling and setting are in progress.

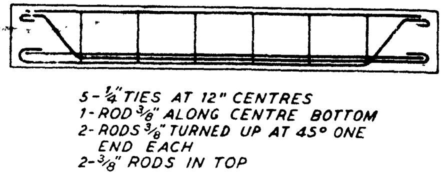


Fig. 11.—Typical reinforcement for 6-ft.-span lintel

It is well to remember that a column base may have to carry a load in the nature of a hundred tons, and such a load needs good workmanship.

Lintels

Lintels, although often relieved of much of their loads by the arching of brickwork above them, deserve as much care as any other part of a building, especially in those cases where beams run into the walls above them. It is not sufficient to lay two or three odd lengths of ½-in. bar in the bottom, and be satisfied that they are reinforced. Allowance should be made for shear, as explained in the section on beams, and the stirrups wired securely. The sketch (Fig. 11) shows a typical reinforcement for a 6-ft.-span lintel, with the cover of 1 in. clearly indicated.

When they can be precast time is saved by constructing a multiple mould, stop pieces being used to achieve the required length.

Columns

In constructing reinforced-concrete columns it is difficult to realise that concrete capable of carrying, say, 40 tons on a square foot should need steel to assist it, but the filling of the column boxes a few feet at a time results in a series of almost isolated blocks sitting one on the other. Steel rods act, therefore, as connecting dowels. There is another reason for the use of reinforcement where a somewhat slender column carries a beam which has been cast so as to be monolithic with the former. Loading of the beam produces a small but measurable deflection, and this in turn tends to bend the column, the upper portion bending outwards and the lower inwards.

To prevent buckling of the rods they are tied together by stirrups wired to them at intervals.

Where columns have to carry large loads it is frequently an advantage to have some part of the compression carried by the steel, each square inch of the latter replacing 15 sq. in. of concrete. In such cases six or

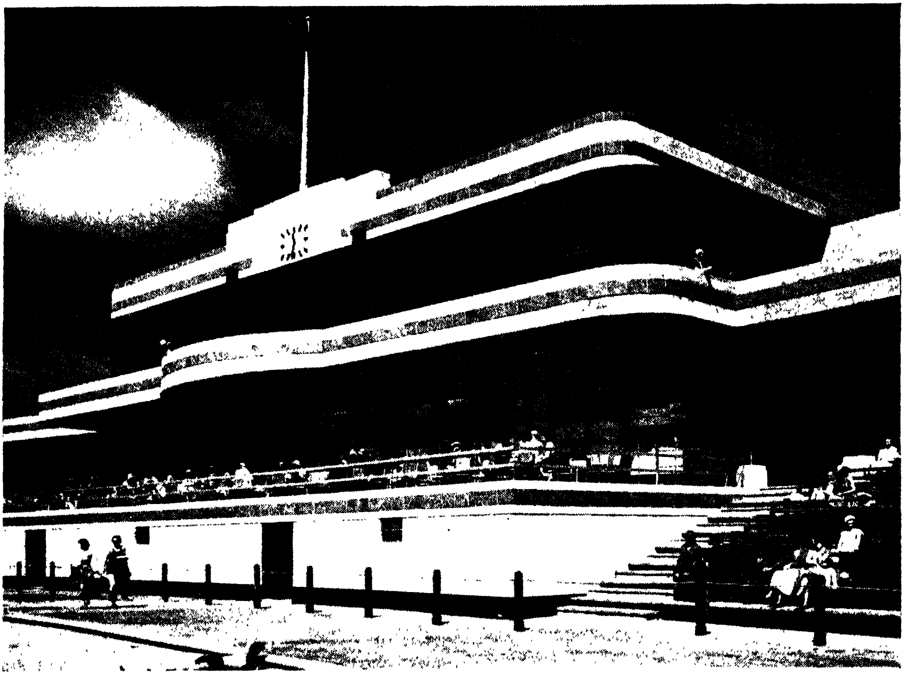


Fig. 12.—CAFÉ AND TEA TERRACE, NEW BRIGHTON BATHING POOL, EMBODYING THE USE OF REINFORCED-CONCRETE BALCONIES AND CANOPIES CANTILEVERED OUT FROM THE MAIN WALLS

Surfaces rendered in "Snowcrete," with continuous bands of permanent colour in black and green faience. (*Architect—L. St. G. Wilkinson, M.Inst.C.E., Borough Engineer, Wallasey.*)

eight bars are used, and great care must be taken with the binding and the ramming of the concrete. To assist the latter, inspection traps are left in the shuttering, so that the work can be inspected as it proceeds.

Precast Roof Trusses

The advantages of casting trusses on the ground are numerous, and this method is becoming popular but needs care if good results are to be obtained. The shuttering must be strong, accurate, and of sound timber, well oiled to prevent adhesion. Cross-braces should be used freely, and all arrises slightly rounded.

As there will be a multiplicity of similar trusses it is usual to arrange the mould so that after the casting of the first truss the former can be raised by the addition of further widths of board, thus allowing the casting of four or five trusses one on top of another, paper being placed between successive layers of concrete to prevent adhesion.

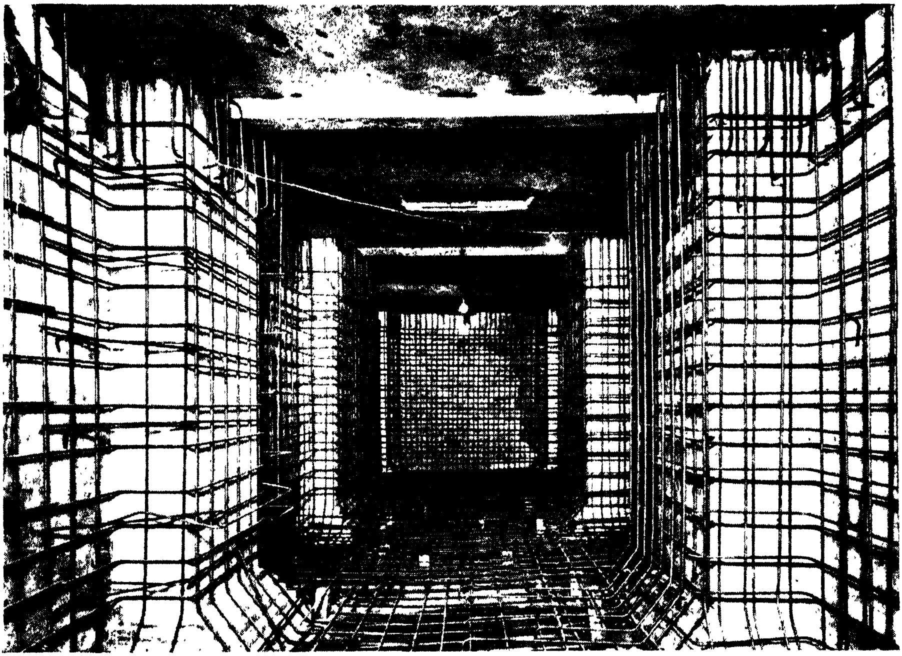


Fig. 13.—REINFORCED-CONCRETE TANK

Here we see the reinforcement of the inside concrete casing of a water tank 11 ft. deep, at City Gate House, Finsbury Square, London, the walls and bottom 9 in. thick throughout, reinforced with steel rods on both sides, with $\frac{5}{8}$-in. diameter rods at 9-in. centres. The mixture of concrete used was 1 part Portland cement, $1\frac{1}{2}$ part clean washed sand, and 3 parts washed ballast to pass $\frac{3}{4}$-in. mesh. (*Architects: Sir G. Gilbert Scott and F. R. Gould Wills, F.R.I.B.A.*)

Eagerness to see the trusses hoisted should not be allowed to prevent the longest possible time being given for hardening, and when the actual hoisting is done the slings should be placed so that the truss is lifted in the position it will occupy under load, a pair of stout deals being lashed alongside to prevent damage, and to strengthen it.

All necessary holes can be cast in the members by the insertion of tubular sleeves, which will also allow of the use of through bolts to stiffen the mould.

As in every other branch of building, experience is the best teacher, but with some slight idea of the principles underlying reinforcement there should be no excuse for such blunders as having several tons of reinforcement left over from a job, nor should it be possible to excavate a faulty concrete road and find the reinforcement under the concrete instead of in it.

Formwork is dealt with in Chapter IV, and it is unnecessary to

say anything further about it except that it cannot be too strong, for once concrete has bulged nothing short of superhuman efforts will get it back into position.

Placing of Concrete

The placing of concrete needs as much care as any other part of the work, particularly when the reinforcement is complex. It is good practice to commence filling with a more fluid mix than will be used in the bulk, but this is not to be taken as meaning that more water is to be added per batch. The same result can be achieved by a reduction in the amount of the aggregate, and the slight extra cost in cement per cubic yard of mix is well worth while, the exposed faces of the work being dense and of good appearance instead of requiring filling and patching.

Ramming should be done with thin tools, whatever be used. Blunt rammers tend to trap the larger particles and force them to the bottom of the form, where they are a hindrance to the flow of the mortar beneath the steel. The secret of good work is to fill in thin layers, not in heaps at one end, trusting to the mixture to flow lengthwise along the form. Another advantage of thin layers is that far less tamping is required.

Filling Slabs

In filling slabs they should be partitioned off in strips by means of narrow boards set edgewise, and notched to pass the rods ; in this way the noon whistle rarely finds a section so incomplete that it cannot be finished in a few moments. If it is absolutely essential to suspend operations the joint should be made as near the centre of the span as possible, never near a support. On resuming work, the old concrete should be roughened, washed free of dust, and coated with rich cement grout.

Beam Boxes

Beam boxes should be well spaded along the sides, to free air bubbles and work a good face, and a handy tool can be made from 10 or 12 in. of 3-in. by $\frac{1}{8}$-in. mild steel drilled and screwed to a piece of "two by four." Another useful dodge is the use of a portion of expanded metal fixed in the same way, the meshes turning the particles over and over as it moves up and down.

Concrete should be placed as rapidly as possible after mixing, and never after twenty minutes, though even this is too long and quite unnecessary if the job is thought over beforehand.

Concrete left longer than twenty minutes should never be rewetted. The proper place for it is the rubbish pile.

After Filling the Forms

Many users heave a sigh of relief when the forms are filled, and turn to the next job, but there is still something to do if good results are

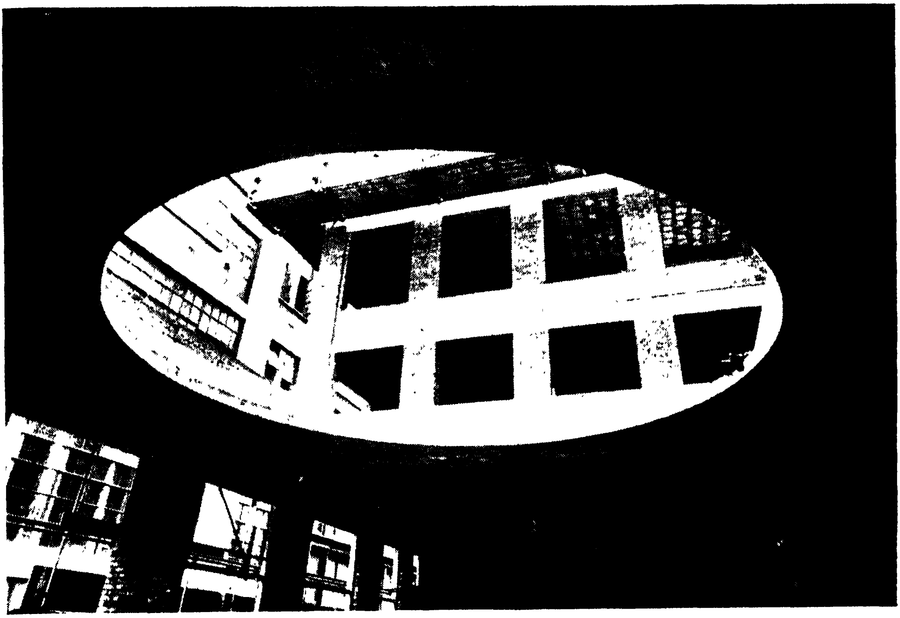


Fig. 14.—Concrete flat to take glass dome

wanted. The concrete must be kept damp for some days, so that it may harden slowly. Buildings under construction are invariably draughty, and the resulting wind dries exposed concrete too rapidly.

Daily watering from a rose will produce hard, dust-free surfaces.

Pleading guilty to the lighting of fires to keep the thermometer at the level desired by the architect in cold weather, the writer knows that it is a shoddy way of doing a job. If work must go on, then the water for the mixing, and the aggregates, can be warmed, or more cement used, so as to get extra chemical heat to offset dangers of frost.

It is easy to obtain a reputation for careful reinforced-concrete work, and such a reputation is valuable to builders desiring contracts, and to foremen seeking employment.

Knowing something of the theory behind the design, it remains to use none but the best-quality materials ; to see that mixing is strictly to specification ; that the reinforcement is bent and placed in strict accordance with the drawings ; and, above all, that the concrete be rapidly placed after mixing, and thoroughly well punned.

Concrete construction is becoming rapidly lighter and more graceful, with a resulting need for the highest quality of workmanship to withstand the increasing stresses. Those who are prepared to apply to reinforced concrete the same degree of craftsmanship which they now give to brickwork or joinery will achieve their own reward.

Chapter III

CONCRETE FOUNDATIONS, WALLS, FLOORS, AND ROOFS

FOUNDATIONS FOR PIERS, COLUMNS, AND WALLS

Plain-concrete Foundations

WHERE the loads are comparatively light, or where they do not need to be spread over a large area, plain-concrete footings may be used. In two-storey, semi-detached houses, the load at the base of the external walls is about 1 ton per foot run, and at the base of the party wall about 2 tons per foot run. Assuming that the ground will carry 1 ton per square foot, a mass-concrete footing 2 ft. wide will carry both external and party walls.

It is usually laid down in the design of mass-concrete footings that the thickness of the concrete shall be such that the load can "spread" to the outside edges of the footings at an angle not flatter than 60°.

Reinforced-concrete Column Footings

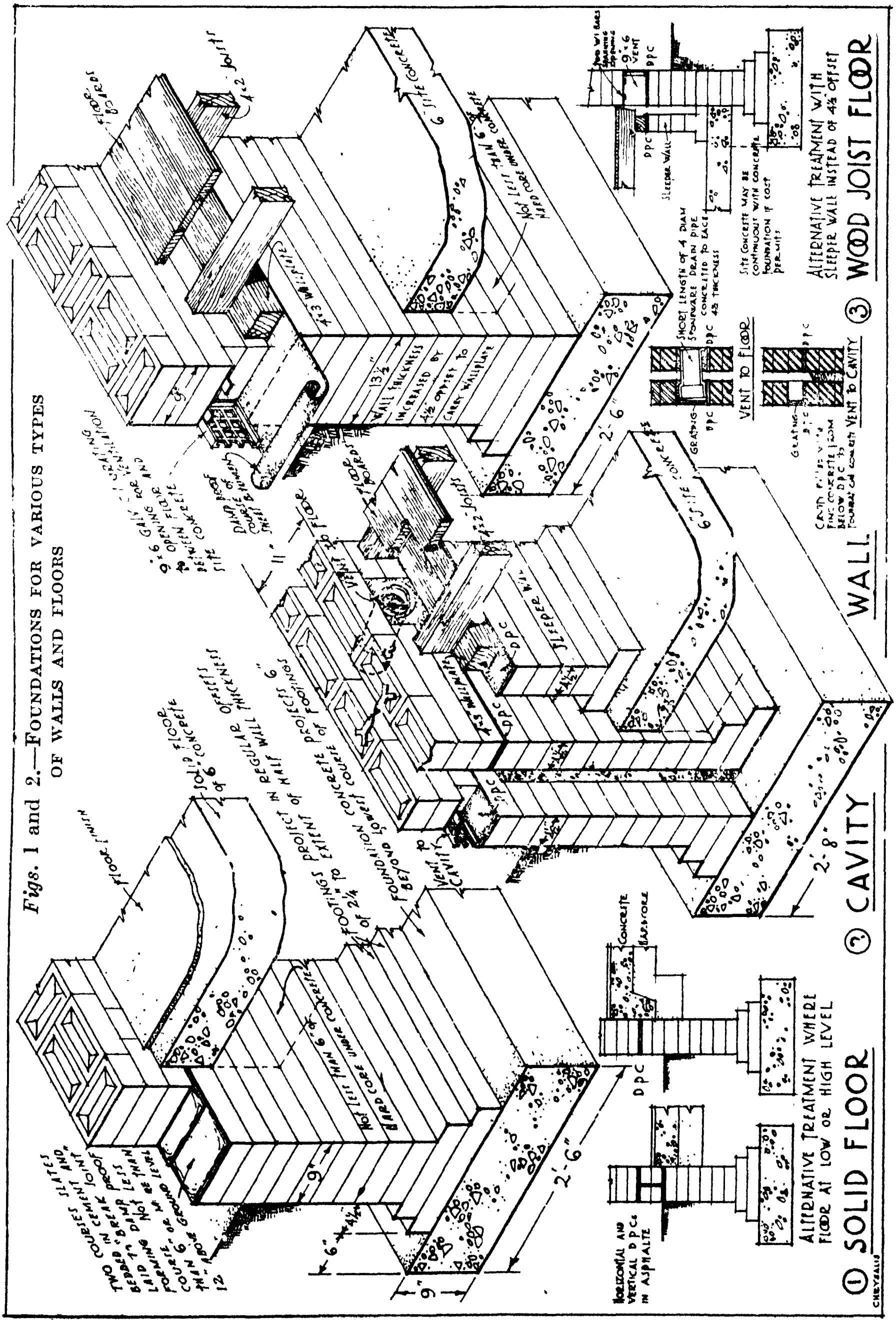
A spread footing for a cast-iron or steel column or for a heavily loaded isolated pier is often built of reinforced concrete. Figs. 3 to 11 show a series of spread footings designed to carry loads of 25, 50, and 100 tons, spread at ½, 1, and 2 tons per square foot.

TABLE I

LOADS ON GROUND

Type of Subsoil	*Permissible Load on Ground. Tons per Sq. Ft.*
Alluvial soil, made ground, very wet sand	Up to ½
Soft clay, wet or loose sand	Up to 1
Ordinarily fairly dry clay, fairly dry fine sand, sandy clay	Up to 2
Firm dry clay	Up to 3
Compact sand or gravel, London blue or similar hard compact clay	Up to 4
Hard solid chalk	Up to 6
Shale and soft rock	Up to 10
Hard rock	Up to 20

A table of standard mixes for foundations is given on page 58.



Figs. 1 and 2.—FOUNDATIONS FOR VARIOUS TYPES OF WALLS AND FLOORS

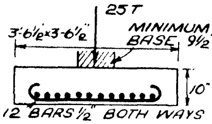


Fig. 3.—25 TONS SPREAD AT 2 TONS PER SQUARE FOOT

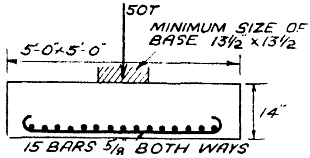


Fig. 6.—50 TONS SPREAD AT 2 TONS PER SQUARE FOOT

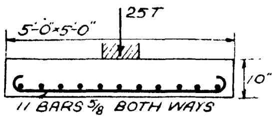


Fig. 4.—25 TONS SPREAD AT 1 TON PER SQUARE FOOT

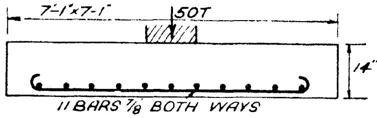


Fig. 7.—50 TONS SPREAD AT 1 TON PER SQUARE FOOT

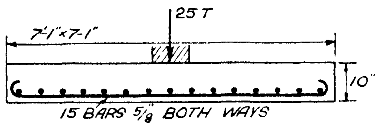


Fig. 5.—25 TONS SPREAD AT ½ TON PER SQUARE FOOT

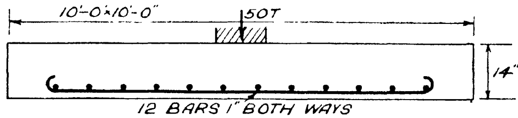


Fig. 8.—50 TONS SPREAD AT ½ TON PER SQUARE FOOT

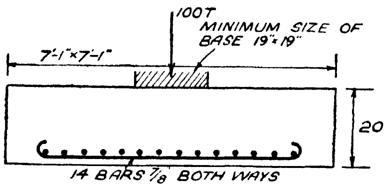


Fig. 9 (*left*).—100 TONS SPREAD AT 2 TONS PER SQUARE FOOT

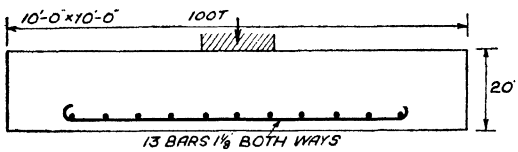


Fig. 10 (*left*).—100 TONS SPREAD AT 1 TON PER SQUARE FOOT

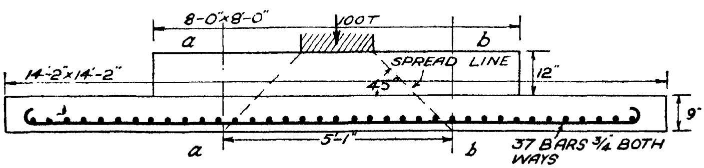


Fig. 11.—100 TONS SPREAD AT ½ TON PER SQUARE FOOT

Figs. **3 TO 11.—REINFORCED-CONCRETE SPREAD FOOTINGS FOR CAST-IRON OR STEEL COLUMNS OR HEAVILY LOADED ISOLATED PIERS**

Stepped Footings

Only in the case of a number of large footings is it worth while to make a stepped footing as in Fig. 11. In all other cases, plain rectangular slabs with flat tops, as in Figs. 3 to 10, are best. If stepped footings are used the upper part must be added within a few hours of concreting the lower part, and the joint must be kept scrupulously clean.

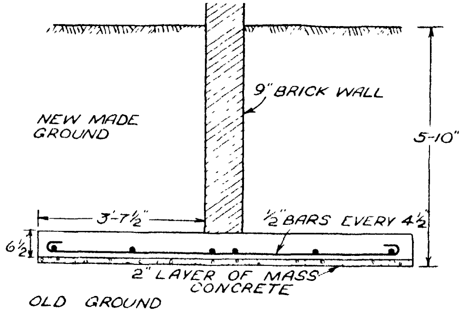


Fig. 12.—Reinforced-concrete wall footing slab

Showing 9-in. wall with load of 2 tons per foot run at base. Ground at depth of 5 ft. is capable of carrying about 10 cwt. per square foot gross weight.

WALL FOOTINGS

Reinforced-concrete Footing Slab for 9-in. Wall

When it becomes necessary to spread the load from a wall over more than about 5 ft., a reinforced-concrete footing slab may be used. Fig. 12 shows a 9-in. wall with a load of 2 tons per foot run at the base of the wall. The ground, at a depth of 5 ft., is capable of carrying about 10 cwt. per square foot gross weight. The earth above the foundation slab weighs about 5 cwt. per square foot, leaving only 5 cwt. per square foot net available for the load on the wall. The footing slab must therefore be 8 ft. wide. The slab is designed as a cantilever of 3-ft. 7½-in. span carrying an effective upward load of 5 cwt. per square foot. A 6½-in. slab reinforced with ½-in. bars at 4½-in. centres is suitable for these conditions.

Footing for 14-in. Wall

A similar footing, but for a 14-in. wall having a load of 6 tons per foot run at the base, is shown in Fig. 13. In this case the ground at a depth of 4 ft. will carry 1 ton per square foot gross. Deducting 4 cwt. per square foot for the weight of filling over the foundation slab, this leaves a net amount of 0·8 ton per square foot, and the footing slab should be 7 ft. 6 in. wide. If the ground is slightly variable, or if the loading on the wall

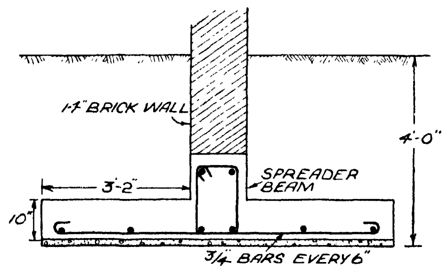


Fig. 13.—Footing slab for 14-in. wall

Load, 6 tons per foot run at base of wall. Ground at depth of 4 ft. will carry 1 ton per square foot gross.

is not quite uniform, a spreader beam may be formed, as shown. The size of this beam can generally be calculated to suit the loading on any given site.

Preliminary Concrete

Before *constructing any reinforced-concrete foundations or footings*, a layer of mass concrete about 2 in. thick should be spread over the site. This has been shown in Figs. 12 and 13, but is not shown in Figs. 3 to 11.

When a Raft Foundation is Required

When the ground is so soft that the footings to walls and columns are so large that they touch one another, then the foundations may be all joined together into one raft which will spread the whole weight of the building uniformly (or very nearly so) over the whole site. A very similar state of affairs may occur on a moderately good site with a very heavy building, such as a grain silo weighing 2 to 3 tons per square foot on plan.

Before deciding on a raft, the engineer must ascertain if there is harder ground at a lower level which could be reached by mass-concrete piers or by piles. On the other hand, the excavation and pumping required for pier holes, or the vibration due to piling, may endanger surrounding buildings, and leave the engineer no alternative but to supply a raft foundation put in at the highest possible level.

The figuring out of a large, complicated, reinforced-concrete raft is a long and difficult process, and must be left to an expert. Speaking generally, a raft with beams in both directions is best for general building work, while flat-slab construction is not very suitable for rafts of any kind except under silos.

It is possible to pass small drainage pipes through the raft beams near mid-span, but any attempt to pass large ducts or sewers at once destroys the strength of the raft in the vicinity. For this reason it is advisable to leave ample clearance between the top of the raft beams and the lowest floor of the building.

Piled Foundations

What may be termed everyday practice in precast piling is as follows :

10-in. by 10-in.	section	up to	25 ft. long
12-in. by 12-in.	,,	,, ,,	35 ft. ,,
14-in. by 14-in.	,,	,, ,,	40 ft. ,,

These piles are usually driven with drop hammers, of the type in Fig. 19, weighing 30, 40, or 60 cwt., with a fall of 3 ft. to 4 ft., to a set of about 1 in. for 10 blows. When so driven they will safely carry loads of 30, 45, and 60 tons per pile respectively. Longer piles may be 16 in. by 16 in. or 18 in. by 18 in. (either solid or hollow), but special care is neces-

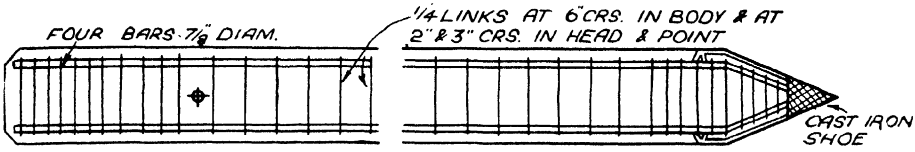


Fig. 14.—14-IN. BY 14-IN. REINFORCED-CONCRETE PILE, 30 FT. LONG

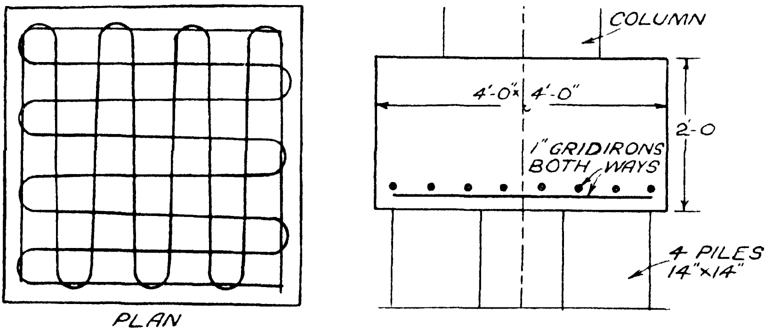


Fig. 15(*left*).—PILE GROUP TO CARRY 240 TONS

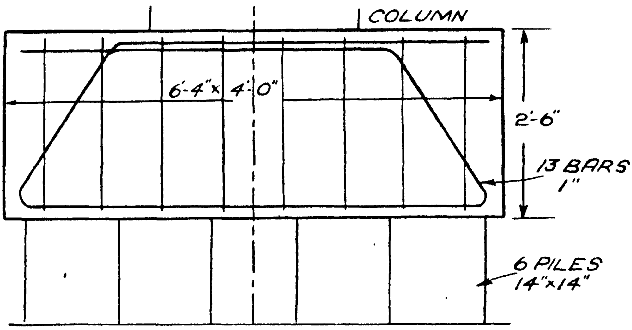


Fig. 16 (*right*).—PILE GROUP TO CARRY 360 TONS

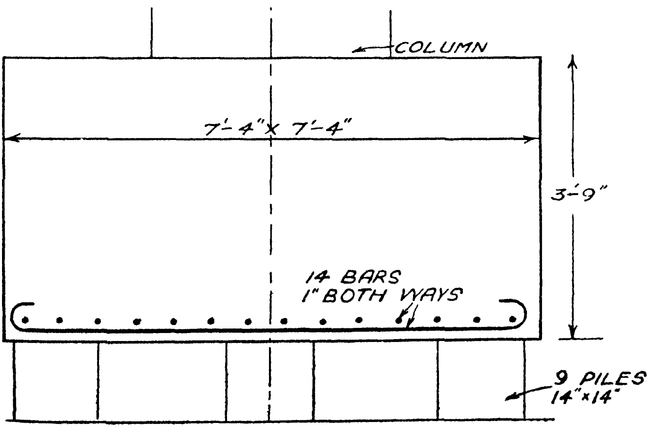


Fig. 17 (*left*).—PILE GROUP TO CARRY 540 TONS

In each cap in Figs. 15, 16, & 17 a different system of reinforcement is shown.

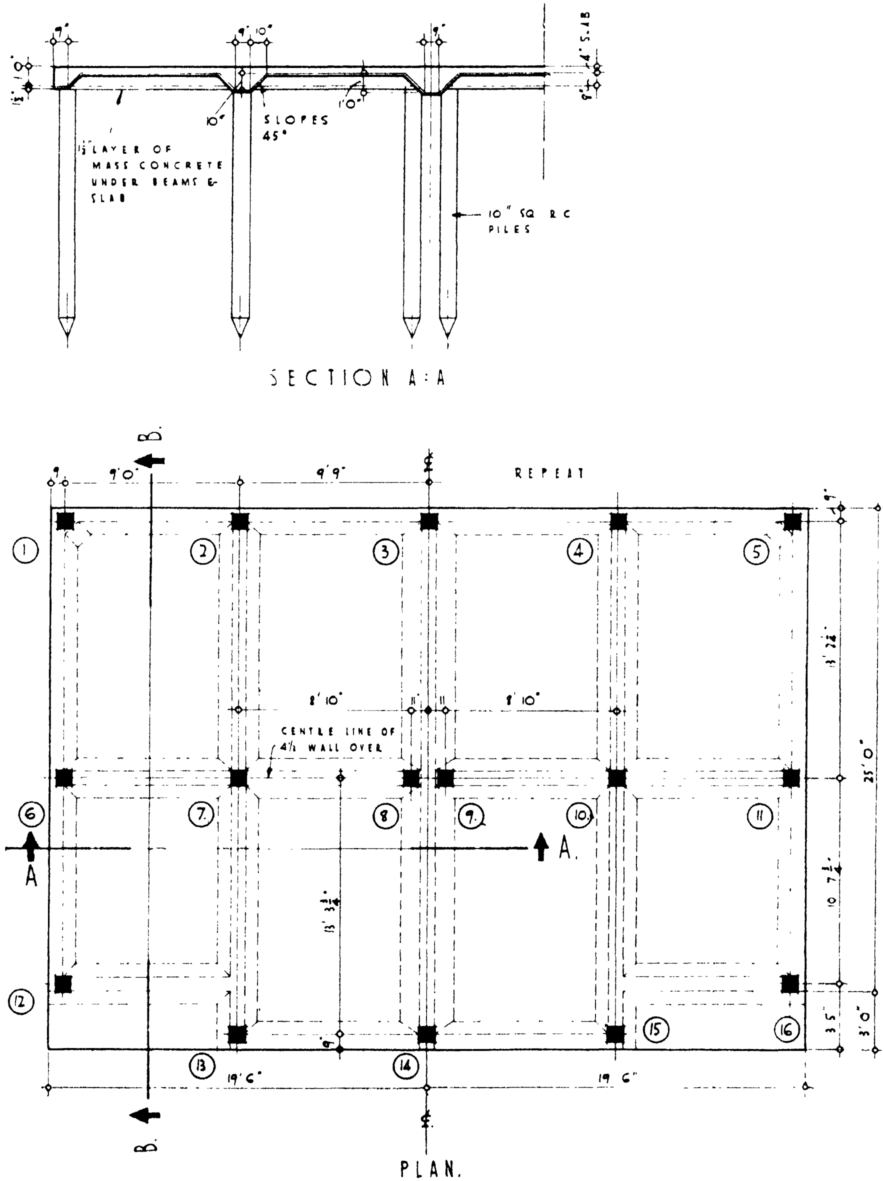


Fig. 18.—PILED FOUNDATIONS FOR PAIR OF SEMI-DETACHED HOUSES
(*Peter Lind & Co. Ltd.*)

sary in making, handling, and driving long piles, particularly when made of modern rapid-hardening cement.

Discretion is needed when driving into sand, as excavation or pumping on neighbouring sites, or even flow of ground water, may allow the sand to loosen and let the piles through.

A completely isolated group of piles should number not less than three. Groups of one or two piles should be connected by tie-beams to neighbouring groups to eliminate eccentric loading.

Some Examples

Fig. 14 is a typical detail of a 14-in. by 14-in. precast reinforced-concrete pile. Figures 15, 16, and 17 show groups of 14-in. by 14-in. piles, with suitable pile caps. The group in Fig. 15 will carry 240 tons ; that in Fig. 16 will carry 360 tons, and that in Fig. 17 will carry 540 tons. A different system of reinforcement is shown in each cap. The main point to watch is the grip-length of the bars. The only failure of a cap which the writer has seen was a bond failure.

Although piles are mostly used under heavy buildings, it is sometimes possible to exploit soft ground for housing estates by driving short piles. Fig. 18 shows the foundations of a pair of semi-detached houses. The cost of these, including 15-ft. piles and reinforced-concrete slab and beams, was about £65 per house. A usual type of pile frame is shown in Fig. 19. Some modern frames are mounted on travelling undercarriages which span the site, and the frame moves about in both directions under its own power.

A rough idea of the cost of making and driving reinforced-concrete piles may be obtained by calculating the total volume of concrete in cubic yards. A job with about 200 short 10-in. by 10-in. piles costs about £10 per cubic yard. A job with 1,000 piles, 14-in. by 14-in., of moderate length, costs about £6 per cubic yard.

Foundations and Ground Floors

A concrete floor laid directly on the ground eliminates entirely the timber normally required for the suspended type of floor in a domestic building. The Ministry of Health Model By-laws recommend that the ground surface enclosed in the external walls of a domestic building should be covered with a layer of spade-finished cement concrete, 4 in. to 6 in. thick (see Fig. 1).

Figs. 20 and 20A illustrate methods of construction for good and bad grounds, as suggested by the Cement and Concrete Association. In bad ground the foundation is shown in the form of a raft with suitable reinforcement. In both methods, a damp-proof course of tar, asphaltic compound, or bituminous sheeting tarred over should be laid on top of the lower course of concrete. As this lessens the bond between the lower and

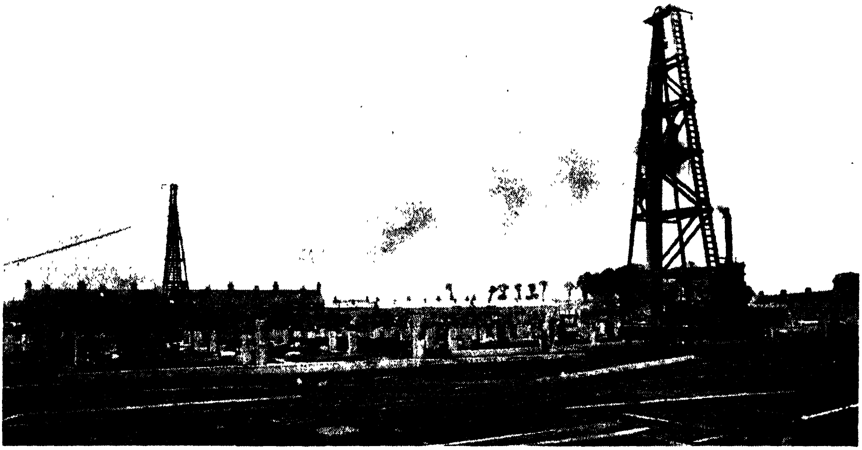


Fig. 19.—Pile frames for pile driving (*Peter Lind & Co. Ltd.*)

Fig. 19a.—Group of 14-in. by 14-in. reinforced-concrete piles after heavy driving

After being driven, the concrete is cut away from the heads of the piles and the projecting bars are built into the pile caps.

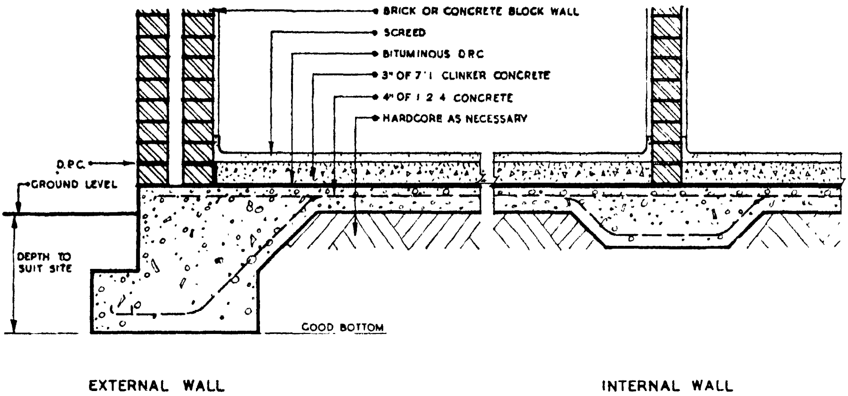


Fig. 20.– CONCRETE GROUND FLOOR WITH RAFT FOUNDATION

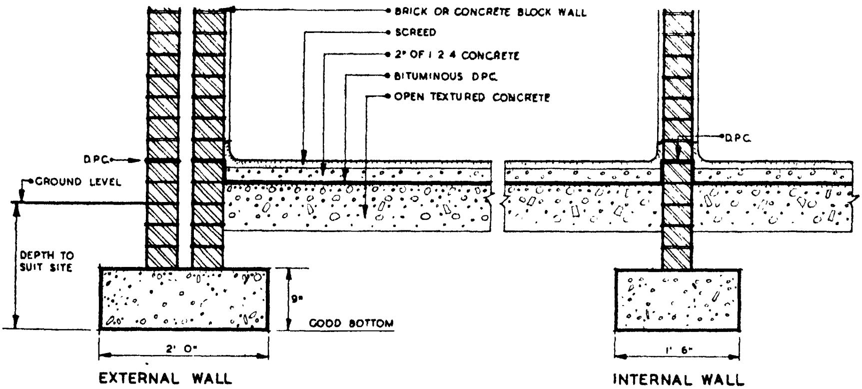


Fig. 20A.—ORDINARY CONCRETE GROUND FLOOR

top courses of concrete it is essential that the top course should be 2 in. to 3 in. thick in order to prevent lifting.

In the case of the raft, it is suggested that the top course of concrete be made with a light-weight aggregate and finished off with cement screed. In the other case, open-textured concrete provides the necessary insulation.

Use of Reinforced Concrete in Buildings

The use of reinforced-concrete construction in buildings may be divided into two general applications :

(*a*) Buildings in which reinforced concrete is used to carry all loads to the foundations, and

(*b*) buildings in which reinforced concrete units are used to take the place of the traditional materials such as timber or steel, because of lack of supply, lower cost, or increased resistance to fire.

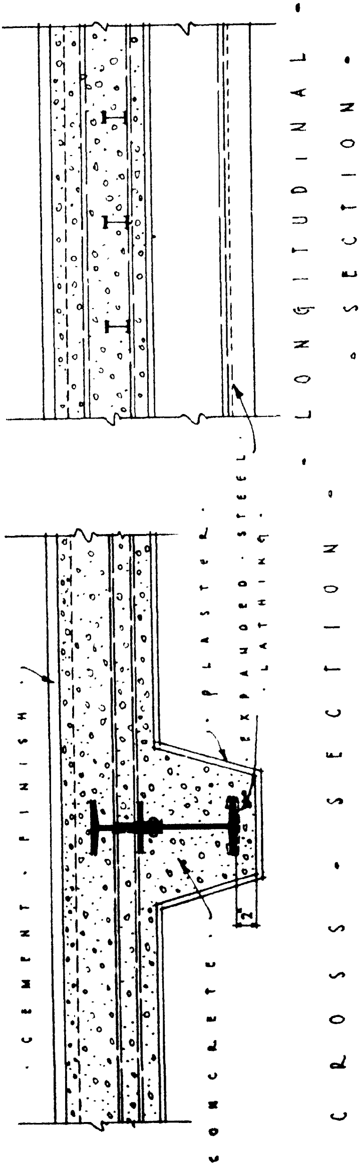


Fig. 21.—Steel Joist and Concrete Floor

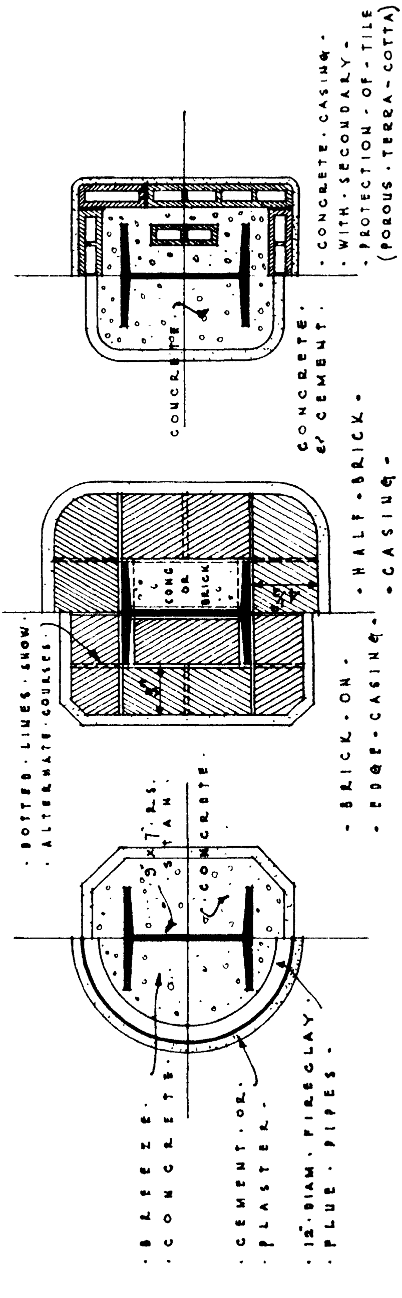


Fig. 22.—Methods of Fire Protection of Rolled-Steel Stanchions with Concrete

Buildings in which reinforced concrete is used to carry all loads to the foundations may be divided into three general types :

(1) The most common type are frame buildings of beam and column construction with brick or concrete infilling wall panels which are not used for load carrying.

(2) Buildings similar to the above, but in which reinforced concrete walls are used to assist in carrying the loads of the building either as beams or as columns or as both.

(3) Buildings of flat slab construction in which the floor is carried directly on the columns without the use of beams or girders.

FLOORS AND FLAT ROOFS

Steel and Concrete Floors

Structural steel—that is, stanchions, girders, and joists—with an " infilling " of concrete, has long formed a well-recognised floor in this country. In Fig. 21 it will be seen that the filler joists are surrounded with concrete.

Protection from Fire

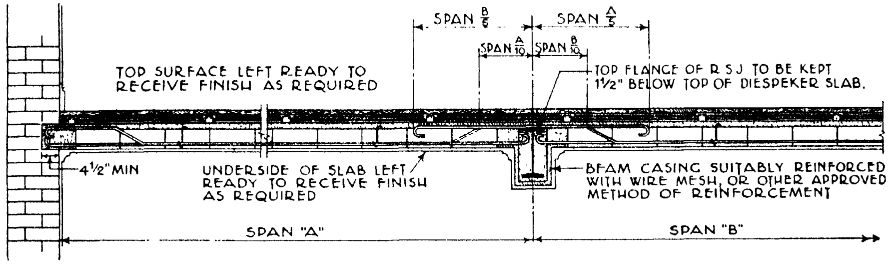
The protection of steelwork in buildings from fire is of vital importance ; such protection is afforded by concrete, brick and concrete, or terra-cotta. It is considered necessary to afford a minimum protection of 2 in. to main steel members in a building, and the soffits or undersides of all steel supporting members must be protected by concrete or terra-cotta. Fig. 22 shows methods of providing this protection to steel stanchions.

Filler Joist, Hollow Tile, and Concrete Construction

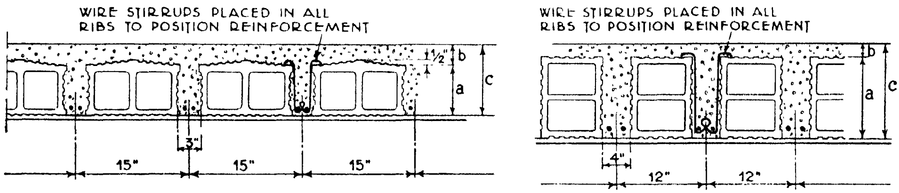
The rolled-steel filler joist type of floor with infilling of concrete needs shuttering. It has the further disadvantages of being heavy and not particularly economical, owing to the fact that the compression flange of the joist and the concrete cannot both be used to full advantage. Various flooring systems have been developed to overcome these disadvantages while retaining the use of the filler joists. These consist of hollow tiles laid side to side with their ends resting in the flanges of the joists, the whole being covered with concrete.

Reinforced-concrete Floors

In reinforced-concrete slab-floor construction, no filler joists are required. The tension flanges of the filler joists are replaced by rods and the compression flanges by concrete. Shuttering is, of course, needed over the area of the floor.

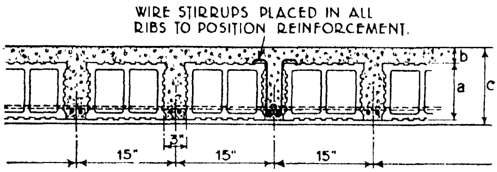


TYPICAL LONGITUDINAL SECTION—SINGLE-WAY REINFORCEMENT

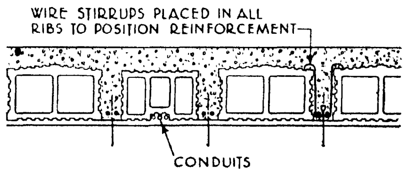


TYPICAL CROSS SECTIONS—SINGLE-WAY REINFORCEMENT

That on the left is for slabs from 4½ in. to 11 in. thick; the cross section on the right is for slabs from 11½ in. to 14 in. thick.



TYPICAL CROSS SECTION OF TWO-WAY REINFORCEMENT



METHOD OF HOUSING CONDUITS

Fig. 23.—DIESPEAKER HOLLOW-FLOOR CONSTRUCTION

Hollow-block Floor Construction

The next step in reinforced-concrete construction was the T-beam floor, in which the lower two-thirds of the slab was omitted except for a series of reinforced-concrete ribs spaced at suitable centres. The space between the ribs is usually filled with some form of hollow block, made of concrete, baked clay, or expanded metal. The hollow blocks, besides simplifying the formwork problem, provide a flat soffit and improve the sound- and heat-insulating qualities of the floor.

Fig. 23 shows an example of this type of construction. The floor consists in a series of rows of standard-size hollow blocks, spaced a given distance apart on temporary formwork. Reinforcing rods are laid between the rows and the concrete is cast and carried above the tops of

the blocks so that the floor is in the form of a series of reinforced-concrete T-beams. The concrete is used only to take the compression and shear, the tension being taken by the steel-rod reinforcement.

Hollow tile reinforced-concrete floors, as well as solid reinforced-concrete slabs, can be designed to span in one or both directions. Two-way reinforcement has the advantage that a slightly decreased depth of slab is required for a given span and load.

Precast Concrete Floors

There are a number of precast concrete floors, in which timber centering or strutting is largely dispensed with. As precast units for floor or roof construction are cast to exact lengths, it is particularly important that any bearing walls on which the units are to rest should be set out accurately and plumb.

The Siegwart floor illustrated in Fig. 24 is an example of precast construction. This floor consists of a number of hollow precast beams laid side by side and grouted together, the grouting space between the beams being about 1 in. No supports or centering are required for fixing. The precast beams span direct between the main bearings, being made to correct lengths, and delivered fully matured, with ends designed to suit the type of bearing provided. The beams are made in lengths up to 20 ft. with depths varying according to the span and loading, from 4½ to 10 in. Each precast beam is reinforced with steel bars in the lower corners, and has oblique grooves cast on the sides to grip the jointing material.

Another type of precast concrete floor is shown in Fig. 25, consisting of pre-fabricated concrete webs and tubes (Cooke's armoured tabular floor). The webs are placed at approximately 10-in. centres and tubes laid between them. The whole is covered with a top layer of 3½ to 1 concrete cast *in situ*. The concrete webs have a mild-steel corrugated

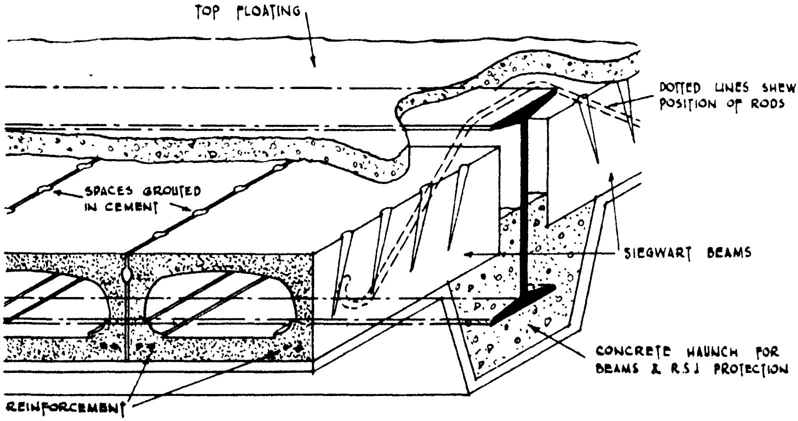


Fig. 24.—SIEGWART PRECAST CONCRETE FLOOR

reinforcing bar embedded in the lower flange. The tubes consist of light, hollow, coke-breeze concrete, 9 in. long.

Fig. 26 shows yet another example of a concrete floor, combining reinforced concrete, precast filler joist units with *in situ* reinforced concrete. In this case the precast units are R.C. beams with infilling consisting of precast aerated concrete filler blocks. Mild-steel rods are threaded through the beams, and the whole is covered with a layer of surface concrete. Continuity is obtained by adding extra rods if desired over the support.

Hardening of Concrete Floor Surfaces

A cursory inspection of the average concrete floor shows that it is neither hard nor free from dusting or disintegration, and as the surface is usually formed by a layer of some such substance as crushed granite, it is evident that the fault lies in the cement compound which binds the granite particles together.

Why Floor Surfaces Come Loose

The procedure adopted in floor construction is roughly as follows. The base concrete is dumped and fairly well rammed, and being easily got at is also reasonably dry. As the workmen approach the topmost layers, however, they commence to make the concrete more and more liquid for the purpose of being able to float it off to a good surface. This increased water-cement ratio is the beginning of trouble, for as the men trowel or work the surface, the water rises, and they finish off with a perfect coat of laitance which has no enduring qualities and little self-adhesion. As soon as possible a rendering is run on to the base and, being unable to bond with the laitance, frequently comes loose, so that after a while the upper part is nothing but a loose skin which gives to a load, cracks, and disintegrates.

If the water-cement ratio is kept low, the whole of the laitance

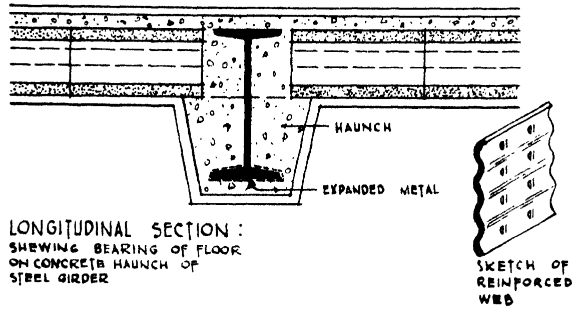


Fig. 25.—PRECAST CONCRETE FLOOR CONSTRUCTED WITH REINFORCED-CONCRETE WEBS AND HOLLOW COKE-BREEZE CONCRETE TUBES

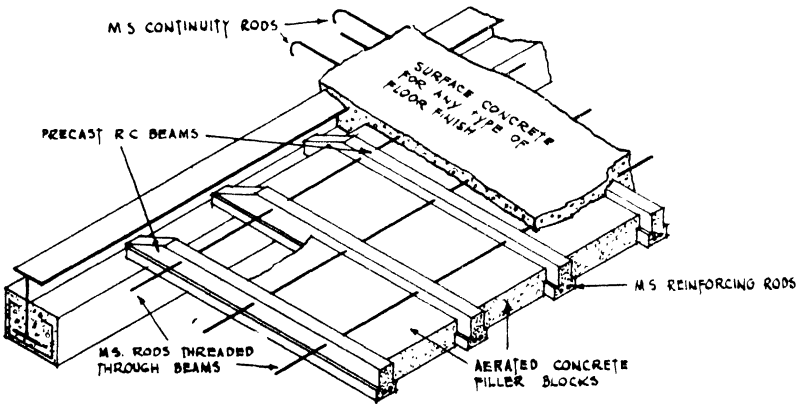


Fig. 26.—PRECAST CONCRETE FLOOR USING REINFORCED-CONCRETE BEAMS AND AERATED CONCRETE FILLER BLOCKS

hacked off, and the hacked base properly brushed off so that no dust is left on it, the top rendering does not come loose.

Renderings should if possible be laid at the same time as the base. The dusting of too wet concrete with dry cement should be absolutely prohibited. It will never form a good surface.

Another fault is over-trowelling; the semi-hardened, interlaced crystal formation breaks and causes cracks.

Use of Hardeners

Calcium chloride is often recommended as a hardener, the suggested proportion being 1 lb. of chloride to each 1 cwt. of cement. Its actual action is as an accelerator, but it is better to use rapid-hardening cement for this purpose, as the chloride, unless used with great discretion, will weaken the concrete.

Pitched Roofs

Pitched roofs which it is desired should be of fire-resisting construction may be formed of reinforced concrete. For this purpose, reinforced-concrete precast members may be used to take the place of timber members. Roofs with gable ends are the most economical design for R.C. units, as hips, valleys, and irregular roof shapes involve comparatively complicated and costly construction. Purlins should be supported by walls carried up through the ground and upper floors.

Fig. 27 shows a simple method of using concrete for a tile-covered pitch roof, as suggested by the Cement and Concrete Association. In the main, only three units are required: the truss, the ridged tiling slabs, and the eaves unit. The concrete truss may be in one or more parts and all the units may be fabricated on the site or by a specialist firm. The

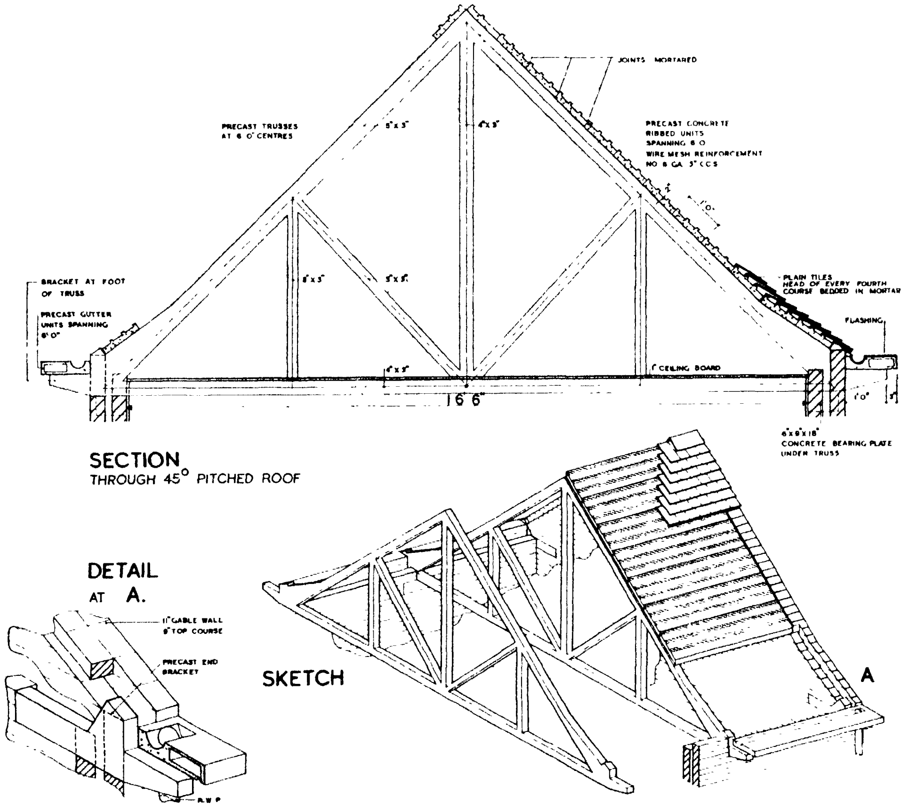


Fig. 27.—EXAMPLE OF CONCRETE CONSTRUCTION FOR PITCHED ROOF, USING PRECAST TRUSSES (*Cement & Concrete Association*)

cross spans are uniform at 16 ft. 6 in. clear. Spans in the other direction have been standardised at about 12 ft. Therefore, the roof trusses should be spaced at approximately 4-ft. or 6-ft. centres. The bottom members of the truss provide a support for the ceiling, which may consist of asbestos-cement sheeting, plaster, or insulating board.

Figs. 28 and 29 shows other methods of using concrete as a substitute for timber in pitched-roof construction. In all cases the size and weight of the precast concrete units required have been kept to a minimum ; purlins, for example, should, for practical purposes, not exceed in 14 ft. length and, unless staggered, should be scarfed over bearing walls.

A satisfactory compromise between normal pitched-roof construction and the flat roof is provided by a lean-to roof of single pitch. The roof covering might consist of asbestos tiles or other material suitable to low

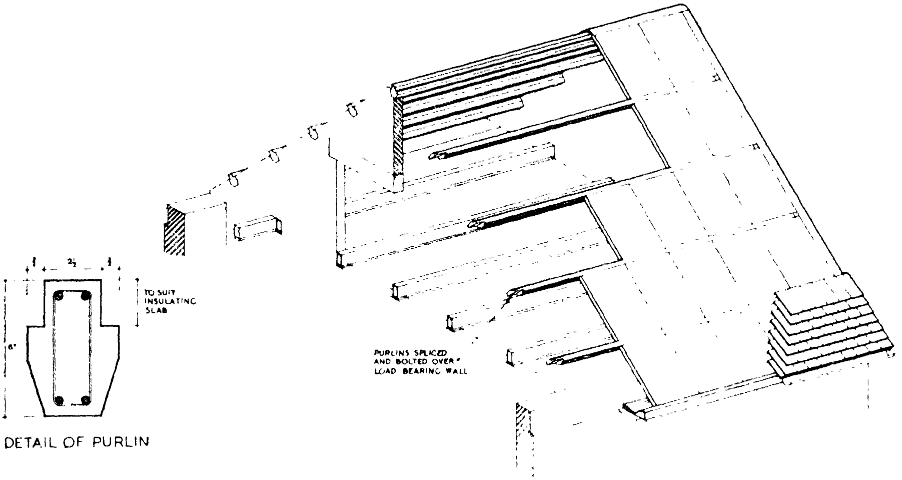


Fig. 28.—CONCRETE CONSTRUCTION FOR TILE- OR SLATE-COVERED PITCHED ROOFS

Showing construction employing precast R.C. purlins with insulating slab infilling. Roof covering is nailed direct to slab.

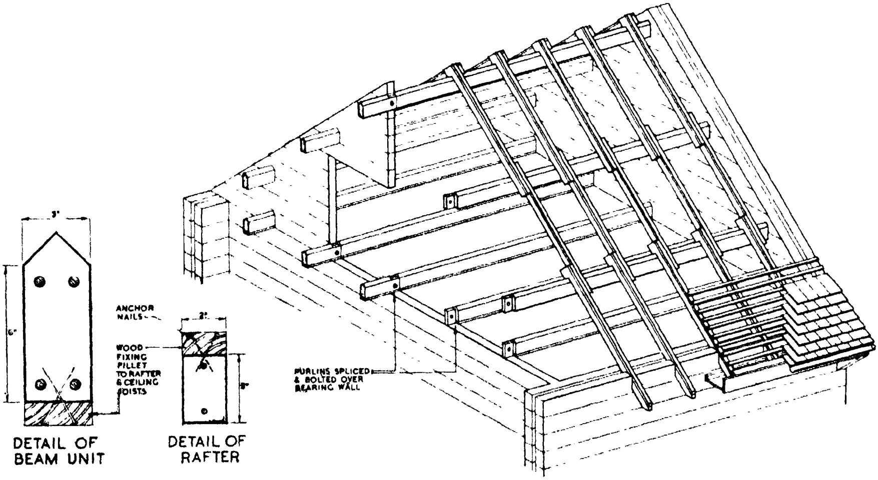


Fig. 29.—PITCHED ROOF WITH R.C. PURLINS AND RAFTERS

pitches and the structural roof of concrete purlins spanning on to the bearing walls.

Eaves can be formed either by cantilevering out the structural roof or using precast concrete slabs, which are tailed down or supported on cantilevered brackets.

With concrete floor construction, the question of trimming for hearths does not arise, since the floor beams can be taken straight into the chimney breast, thus simplifying hearth construction.

Walls

Reinforced concrete has the great advantage that it can be used as a beam carrying itself and other construction and at the same time form a wall. Walls as thin as 4 in. are allowed by regulations.

The interior side of concrete walls are usually lined with 1-in. cork slabs or ½-in. building boards which act as shuttering during construction and as heat and sound insulation afterwards.

If freedom from cracks is desired, a fairly large percentage of steel reinforcement should be used and great care should be taken in arranging this reinforcement near window and other openings.

Wall of Two Qualities of Cement

To combine economy in cement with dense and impervious concrete on outer face (see Fig. 30), place fine-mesh " chicken wire " inside shuttering to separate two different quality mixes—outer concrete mix 1 : 2½ : 4, aggregate ¾ in. and smaller ; inner concrete mix 1 : 2 : 5, using porous aggregate such as pumice or clinker ¾ in. and smaller.

An alternative method of using two different-quality concretes in a wall is shown in Fig. 31. Standard ¼-in. mild-steel plate with handles, or drilled two holes for wire cord, is lowered between shuttering, and raised as filling proceeds. The plate should be quite flat, or it will drag and distort the concrete.

There are a variety of types of standard shuttering systems available for constructing *in situ* walling, both solid and cavity walls, e.g. Wheeler, Whatling, and Franklin systems.

Open-textured Concrete Walls

Solid open-textured concrete walls (see Fig. 29) have been used to a large extent in Scotland for domestic dwellings. Open-textured concrete consists of 1 part cement to 12 or more parts of coarse aggregate varying in size from 1 in. to ⅜ in. with nearly all fines removed.

A wall of open-textured concrete, 8 in. thick, is equivalent in insulation value to at least 11-in. cavity brickwork and the voids formed between particles of aggregate prevent the passage of moisture by capillary movement.

The rough surface of open-textured concrete affords an excellent key

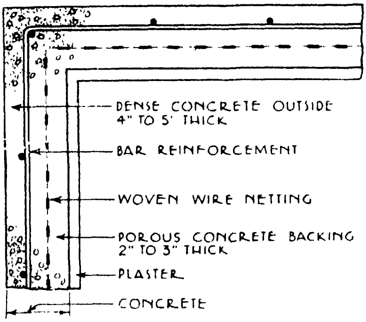


Fig. 30.—METHOD OF ERECTING MONOLITHIC WALL USING TWO QUALITIES OF CONCRETE

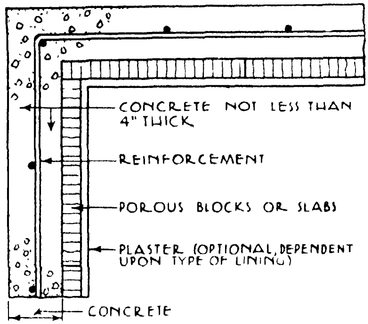


Fig. 33.—WALL HAVING LINING OF POROUS PLASTER OR SLABS

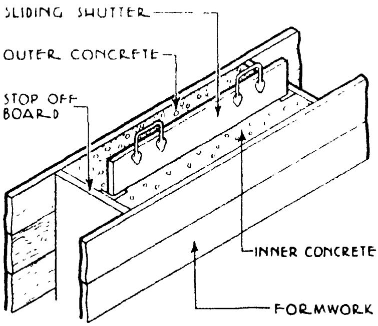


Fig. 31.—ALTERNATIVE METHOD TO THAT IN FIG. 30

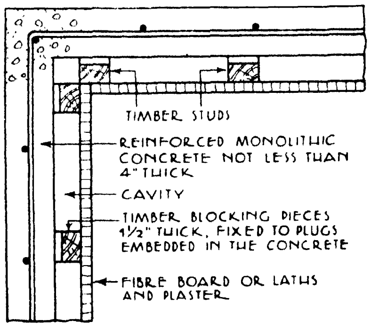


Fig. 34.—WALL WITH LINING OF FLARE BOARD OR LATH AND PLASTER ON TIMBER STUDS

Plugs can be tacked to shuttering as latter is built up.

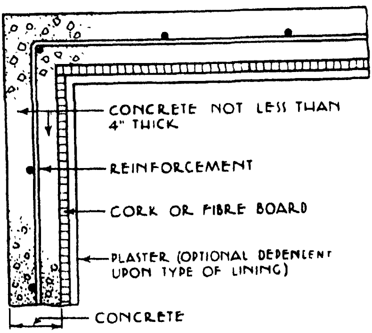


Fig. 32.—R.C. CONCRETE WALL WITH LINING OF CORK, FIBRE, OR OTHER INSULATING BOARD LINING

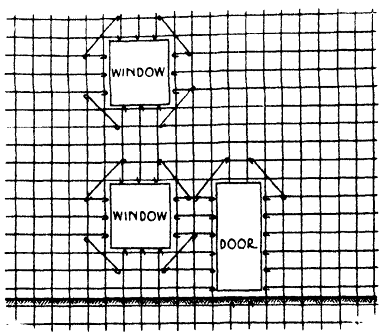


Fig. 34A.—ARRANGEMENT OF REINFORCEMENT FOR THIN WALLS

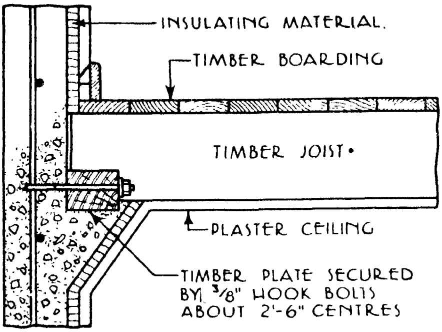


Fig. 35.—Solid R.C. wall with provision for timber floor

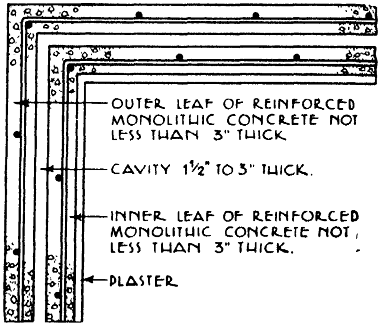


Fig. 36. Cavity wall having two leaves of reinforced monolithic concrete

Cavity walls need expensive shuttering, but patent systems can be hired or bought when doing quantities of repetition work. Mix $1 : 2\frac{1}{2} : 4$, using aggregate $\frac{3}{4}$ in. and smaller. Tamp well.

for rough cast and plaster. The strength of this type of concrete is sufficient for all domestic and light industrial purposes.

Owing to the high proportion of large-size aggregate in the mix, expanded metal can be used for surface formwork. In order to construct *in situ* walling for housing with this type of concrete, the Cement and Concrete Association suggest the use of shuttering formed with expanded metal in precast concrete frames supported by timber posts and runners, spaced by bolts in precast

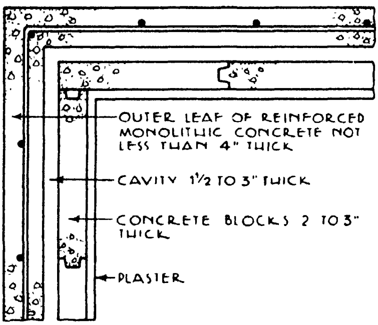


Fig. 37.—Cavity wall having outer leaf of reinforced monolithic concrete and inner leaf of precast concrete blocks

Mix $1 : 2\frac{1}{2} : 4$, aggregate $\frac{3}{4}$ in. and smaller. Wire all rods at intersections. Do not let wires touch shuttering or rust spots will show. Erect breeze-block inner wall after removing shuttering.

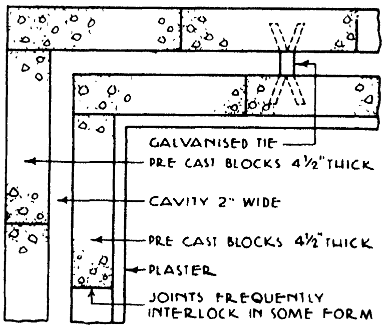
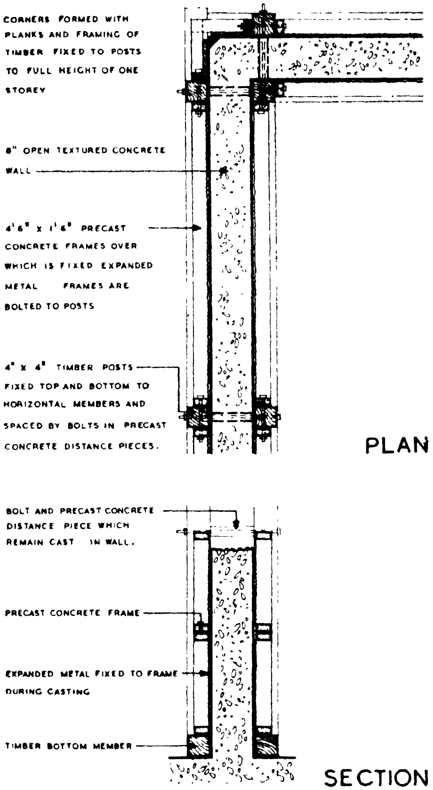


Fig. 38. -Cavity wall of precast concrete blocks

To imitate light-coloured stone with precast blocks, white Portland cement must be used. If wooden moulds are made on job, soak in water for twenty-four hours before using. Paint faces with mould oil. Keep mix dry as possible. Stir in moulds with iron rod or tap sides of mould with mallet.



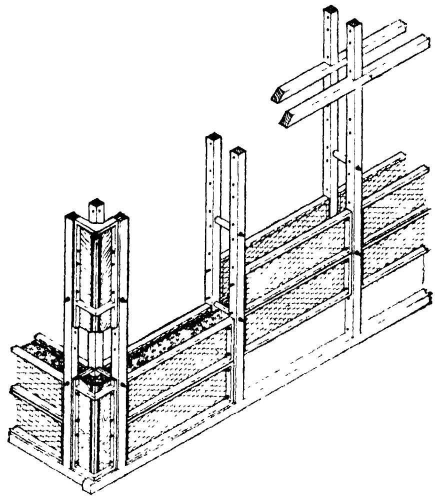


Fig. 39.—OPEN-TEXTURED CONCRETE WALLS

Showing method of constructing this type of *in situ* concrete walling for housing.

distance pieces. When the concrete has been filled to the height of one frame unit, the next unit is bolted in position directly above, and when this has been filled the lower unit is moved up to the next position and so on up the building. Doors and window frames are incorporated in the wall during erection.

How to Erect Solid Walls—Pier and Panel System

Solid walls of concrete can be erected by various methods of fixing the forms. For instance, suppose a wall is required to be erected on the pier and panel system, the dimensions being as follows : 7 ft. between piers, the piers 18-in. face with 4-in. projection, and the height 6 ft. over-all (see Fig. 40).

Amount to Cast in One Operation

It is quite practicable for this wall to be cast in one operation so far as height is concerned, but where high walls or piers are to be erected, the lift should not be more than 3ft. at one operation to avoid excessive side thrust.

To carry out the construction of the forms for this dwarf wall, the pier forms should be in three sections, while the forms for the panel can be in one section.

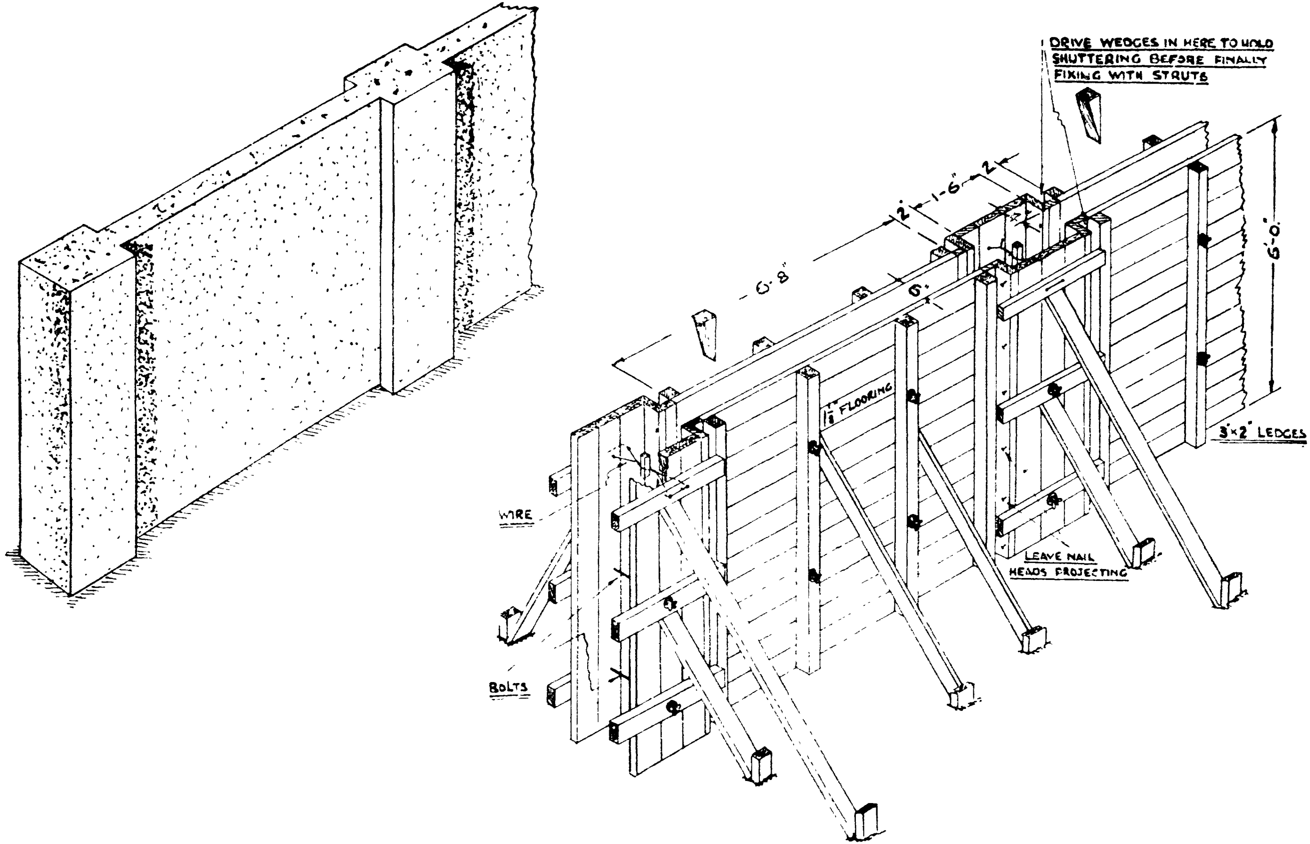


Fig. 40.—Method of erecting solid concrete wall on pier and panel system

The wall is to be 6 ft. high and 7 ft. between piers. Note arrangement of the wire ties in the piers. The forms are fixed together, so as to be easily dismantled without being injured.

The pier sections would be one for the full width of the face, and one on either side returning the internal angle by 2 in. These would be temporarily fixed together and thoroughly strutted in position, thus leaving the length of the panel form to be 6 ft. 8 in., this also should be temporarily fixed to the pier forms and strutted. The arrangement is seen clearly in Fig. 40. A similar process can be carried out on the other side of the proposed wall.

Ties Between Two Sets of Forms

Bolts can pass through the two sets of forms to keep them from spreading when the concrete is poured, or wire ties can be utilised in a similar way and twisted taut until the necessary distance required between the forms is obtained.

Using Tie-bolts

Should bolts be used they should be greased before the concrete is poured, as they must be withdrawn when dismantling the forms, and the holes left in the concrete through their withdrawal filled in at some later time.

Using Wire Ties

In the case of wire ties being used, these can be cut and left flush, but may cause rust stains on external work unless cut back and filled.

This type of fixing would be easy to dismantle without injury to the forms.

Ceilings and Beams

Similar methods to the foregoing can be utilised in fixing forms for ceilings and beams, but in this case, of course, double shuttering would not be required.

Reinforced-concrete Buildings

The formers which are used in the construction of reinforced-concrete buildings may be built up from wood planks or may be built up from steel plate sections such as are used in the Metaform system. Owing to the great depth of shuttering which is required in many instances, special care is needed both in the design and the construction of these forms.

It will be appreciated that when concrete is in a liquid or semi-liquid state it behaves very much the same as water in so far as the pressure effects are concerned.

Thus, if the form for a 10-ft. high column were filled in one shift, the pressure per square foot at the bottom of the form would be about 1,300 lb.

Again, where wide spans have to be constructed of concrete or reinforced concrete, the dead weight of the concrete while it is still in the semi-

liquid form may set up very considerable bending stresses in the shuttering which must, therefore, be designed in such a manner that these stresses are taken care of.

All these points are dealt with in detail in the next chapter.

TABLE II

STANDARD MIXES FOR FOUNDATIONS (PER CU. YD.)

Purpose	*Max. size of Aggregate*	*Cement*		*Sand*		*Coarse Aggregate*	
		cu. ft.	*lb.*	*cu. ft.*	*cwt.*	*cu. ft.*	*cwt.*
Concrete foundations	To pass 1½-in. ring	4	370	16	12	24½	20
Reinforced	To pass ¾-in. ring	6	524	15	11½	23	19½
Sub-floors	To pass 1½-in. ring	5	432	15½	11¾	24	19¼

Chapter IV

FORMWORK FOR CONCRETE BUILDINGS

THE weight of concrete depends on the aggregate of which it is composed. It may weigh about 130 lb. per cubic foot, and until it sets, the formwork must be capable of taking the weight and withstanding the pressure of the mixture.

Pressure on Formwork

Freshly mixed concrete, like water, exerts equal pressure in all directions, so the depth of the wet mixture governs the pressure. Fig. 2 shows a column 10 ft. high, and assuming it to be filled in one shift, the pressure per square foot at the bottom would be approximately 1,300 lb. In other words, with every foot in depth of concrete "placed," 130 lb. pressure is added to the bottom layer. In the case of formwork for girders and beams, it is the dead weight of the material, rather than the pressure, which must be considered. The pressure on the sides of girders of, say, 12 in. to 15 in. deep would be about 65 lb. to 70 lb. per square foot. Nails driven through the sides into the edge of the bottom board are sufficient to take this pressure.

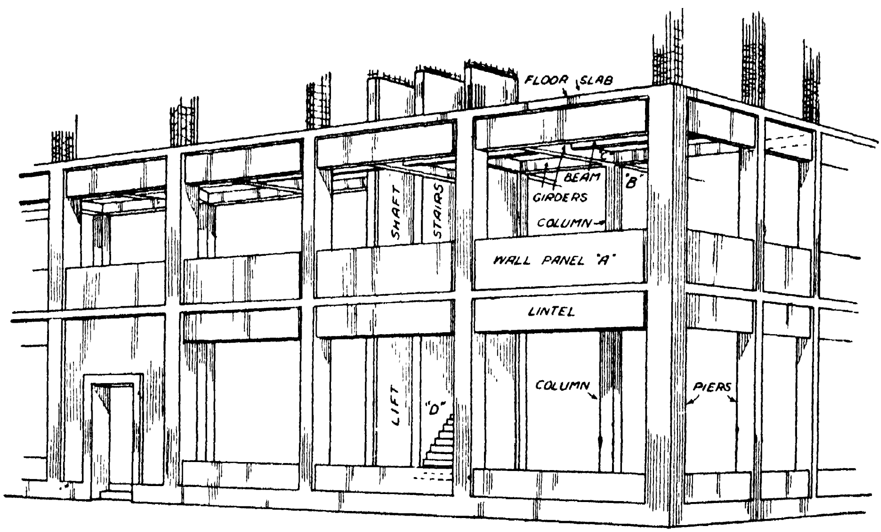


Fig. 1.—General construction of a reinforced-concrete building

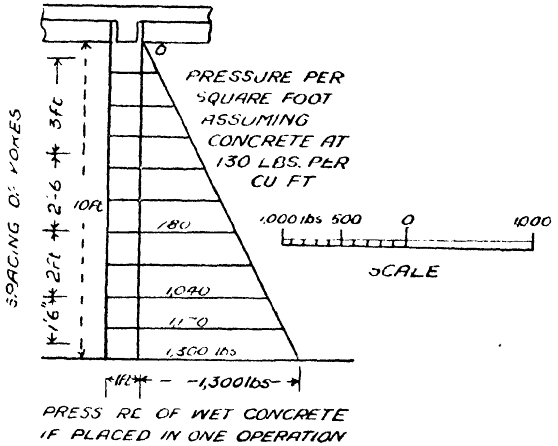


Fig. 2.—Showing pressure exerted by wet concrete

Nailing Formwork

To facilitate "stripping," formwork should be nailed as lightly as possible. If wire nails are left with their heads scarcely driven home, they can be drawn out with a claw hammer, and thus avoid jarring the concrete. Nails driven slightly on the angle will not only hold better, but will be easier to draw.

Spacing of Yokes

As the pressure is greatest at the bottom of a column, diminishing to nothing at the top, it follows that yokes should be spaced closer together where the pressure is most, to prevent the panels bulging. The thickness of the boarding used for panels will also influence the spacing. If 1-in. boarding is used, the two bottom yokes of a 10-ft. column, which is filled in one operation, should be not more than 18 in. apart, and the others as shown in Fig. 2. It is common practice to make the forms for columns a little more than half the complete height, to " place " the concrete, and when this has set sufficiently hard, to move the half-form up and place the remainder. In such cases the yokes may be spaced for the upper half as shown in Fig. 2.

Timber for Formwork

If the finished surface of the concrete is required to be left smooth, the boarding must be " thicknessed " as well as wrought to avoid ridges.

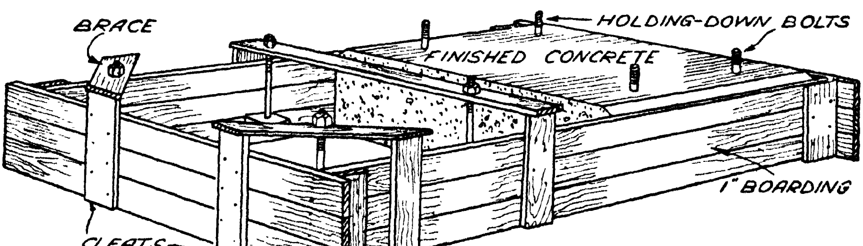


Fig. 3.—Form for concrete machine bed

If, however, the surface is to be plastered, a rough and ridged surface will be an advantage in providing a " key " for the plaster. If the timber is " bone dry," it tends to " cast " and swell when the wet mixture is placed, and in wide panels this might be considerable. Bevel-edged boarding (as shown in detail, Fig. 4) may be used ; the sharp edges will " give," and avoid the accumulated expansion over the whole panel. By damping the outside of the panel, casting will also be avoided.

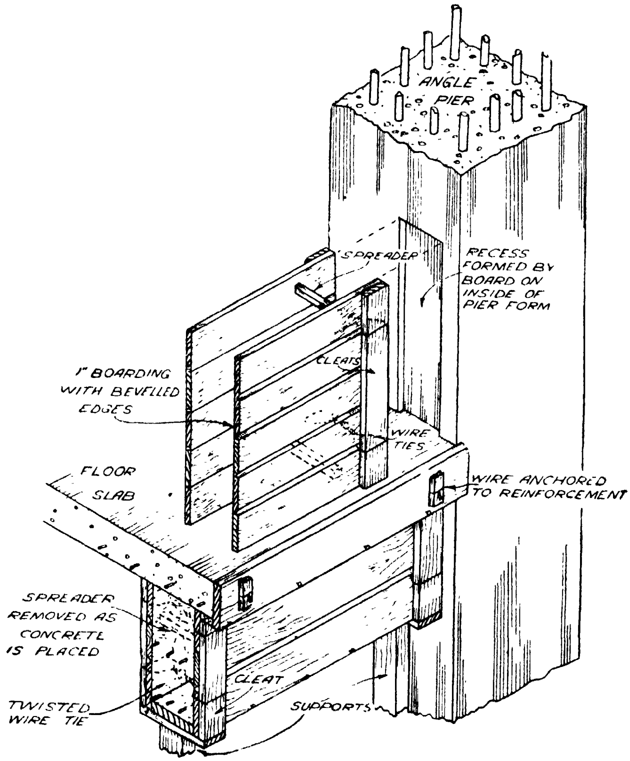


Fig. 4.—DETAIL OF FORMS FOR LINTEL, EDGE OF FLOOR SLAB AND WALL PANEL AT A IN FIG. 1

One-inch boarding is usual for the panels of columns and the sides of girder forms. Bottom boards of beams and girders are better to be $1\frac{1}{2}$ in. thick, they will hold nails better.

Treatment of Formwork

A coat of soft soap and water or mould oil on formwork will facilitate stripping, and leave a better face on the concrete.

Form for Machine Bed

Fig. 3 shows the method of constructing the form for a machine or engine bed. The hanging pieces at the angles also act as braces.

General Construction of Formwork

Fig. 1 shows the general construction of a reinforced-concrete building as a guide to the details which follow.

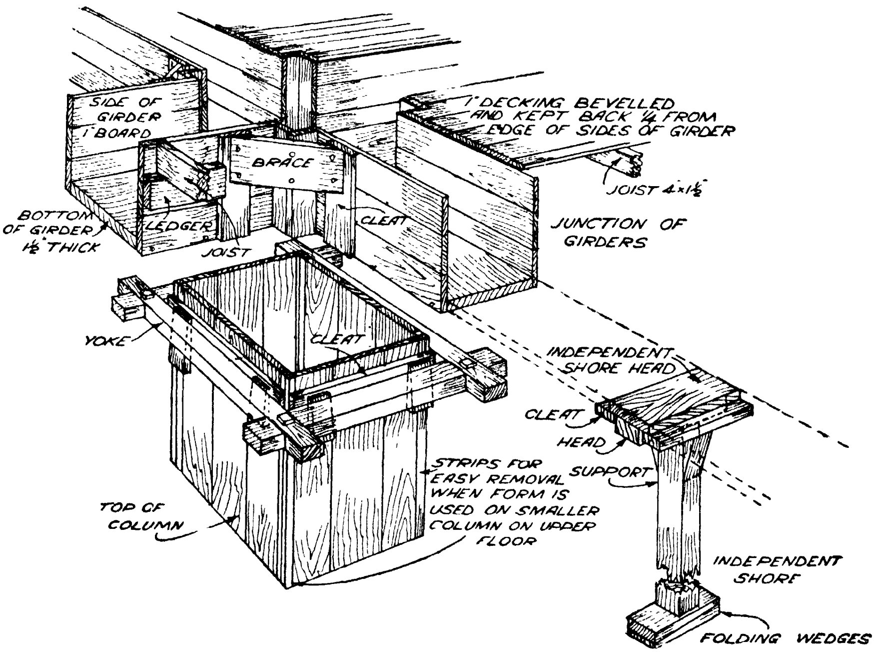


Fig. 5.—FORMS FOR JUNCTION OF GIRDERS AT B IN FIG. 1

Wall Panels, Spreaders, and Ties

Fig. 4 shows the detail of forms for lintel, edge of floor slab, and wall panel at A in key sketch. " Spreaders " are wedged between the sides to maintain the correct space, and wire ties, passed between the boards, round the cleats, and twisted as shown, take the pressure. The spreaders are removed when the concrete reaches their level. The wire ties are cut off close to the surface of the concrete, and punched below the surface, which is afterwards made good. The board for the edge of the floor slab is fixed by wires anchored to the reinforcing rods, and secured as shown.

Bevel-edged Boarding

For the reason already stated, bevel-edged boarding is used on the exposed face of the wall, while square-edged boards are used on the inside. If the joints of the inside sheeting are left slightly open, excessive swelling over the whole panel will be avoided. Expanded metal, which is held in place by the spreaders, bridges the joints between the boards, adheres to the concrete when stripping is done, and provides a key for the plaster.

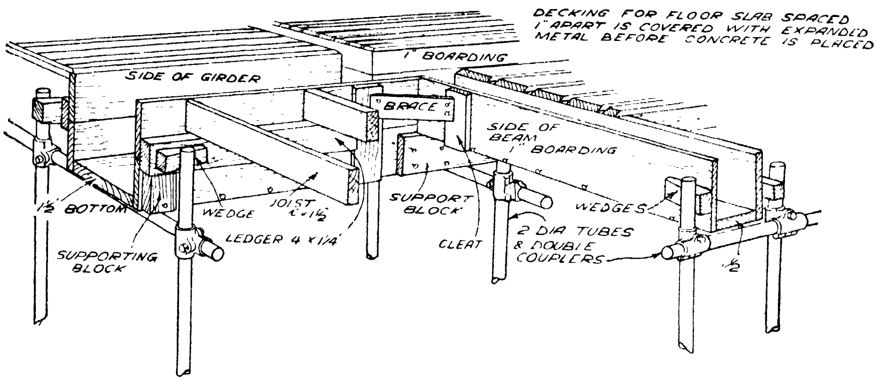


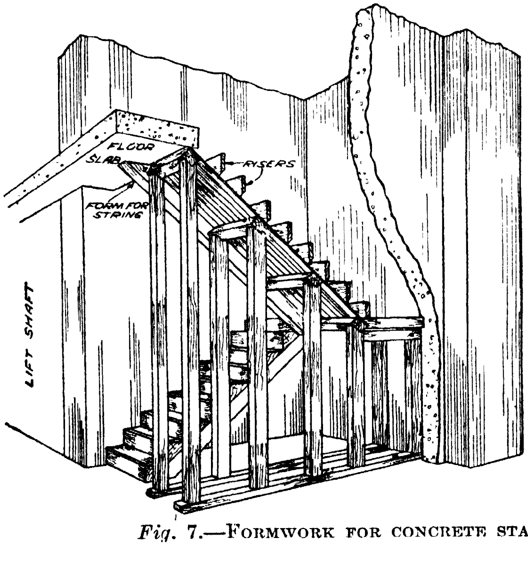
Fig. 6.—FORMWORK AT JUNCTION OF GIRDER AND BEAM AT C IN FIG. 1

Junction of Girders

Fig. 5 (detail at B in key sketch) shows the junction of girders and the top of the column form. The column form is shown with narrow strips at either edge, which when removed will make up the size of the form for the column on the next floor. The yokes are halved at the angles and bolted, and wedges keep the sides tightly in place.

Independent Shores

When the formwork is stripped, for use on the next floor, it is advisable to leave one or more shores for a longer period under girders, to guard



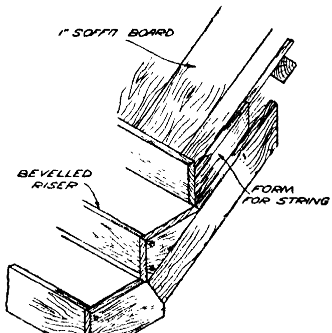


Fig. 7A.—DETAIL OF STRING AND BOTTOM STEP

Fig. 7.—FORMWORK FOR CONCRETE STAIR AT D IN FIG. 1

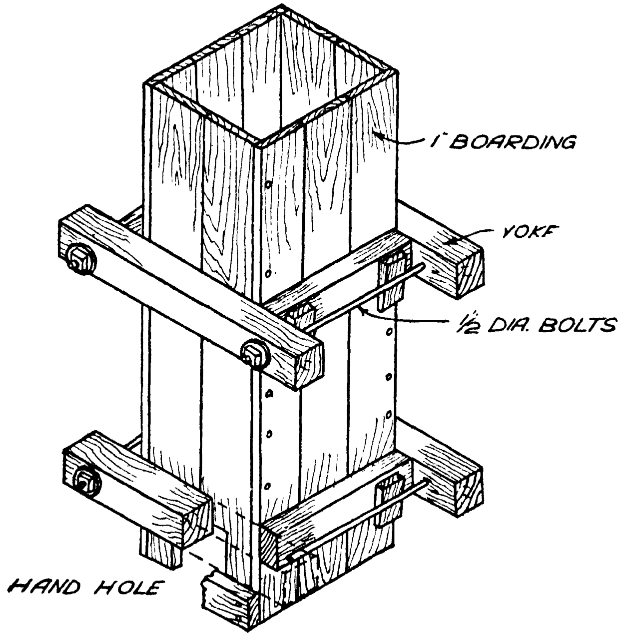


Fig. 8.—Detail of foot of column

against stress in the still rather " green " concrete. In Fig. 5 an independent shore is illustrated. The bottom board rests on cleats, and folding wedges are provided at the foot to allow for easy removal when that can be safely done.

Clearance

In case the sides of the girders bulge slightly, and the concrete grips the ends of the " decking," the edges of the decking should be bevelled and kept back about ¼ in. from the edges of the girder (see Fig. 5).

Junction of Girder and Beam

The junction of a girder and beam is shown in Fig. 6 (detail at C in key sketch). Here the decking is shown, with spaces of about 1 in. between the boards. Fine-gauge expanded metal bridges the gap, and forms a key for the plastered ceiling.

Supports for Formwork

Tubular scaffolding is shown supporting the formwork. It can be used time and again, so apart from first cost it is in the end most economical. Shores which can be adjusted to suit the required height are obtainable, and are extensively used.

Stairs

The formwork for stairs in concrete is shown in Fig. 7 (detail at D in key sketch). Fig. 7A shows a detail of the string and bottom step. The studs supporting the soffit boarding should be racked together ; the

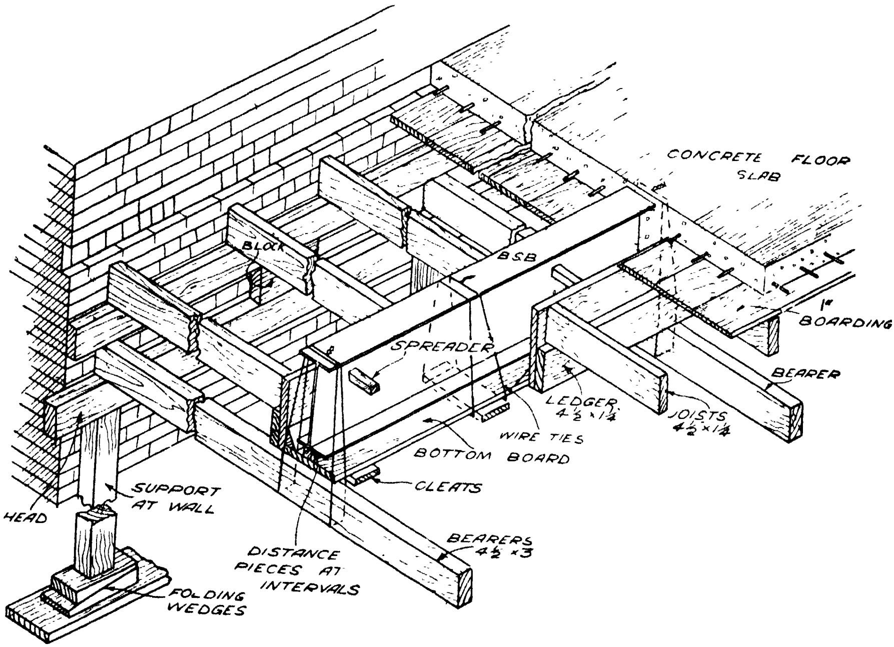


Fig. 9.—Suspended formwork

racks are not shown in the sketch. The concrete is finished level with the top of the risers, which are bevelled on the bottom edge to allow the floating off of the surface to be performed.

Hand Hole

Shavings and other rubbish are apt to collect at the bottom of column forms. If a small hand hole, as shown in Fig. 8, is provided, rubbish can be removed just prior to the concrete being placed. Another type of yoke is here shown, in which ½-in. diameter bolts are used to keep the sides tightly together. The end panels are nailed direct to the yokes, and wedges driven between them and the bolts.

Suspended Formwork

In steel-concrete construction, the beams are used to support the forms for the haunch, soffit, and decking of floor slab. Wire ties, at intervals according to the weight to be carried, are passed between the sides and bottom boards to support bearers, as shown in Fig. 9. The bearers take the weight of the beam form, and additional support may be given by ties at intermediate cleats. Spreaders between the web of the beam and the sides maintain the correct width. Distance pieces (small

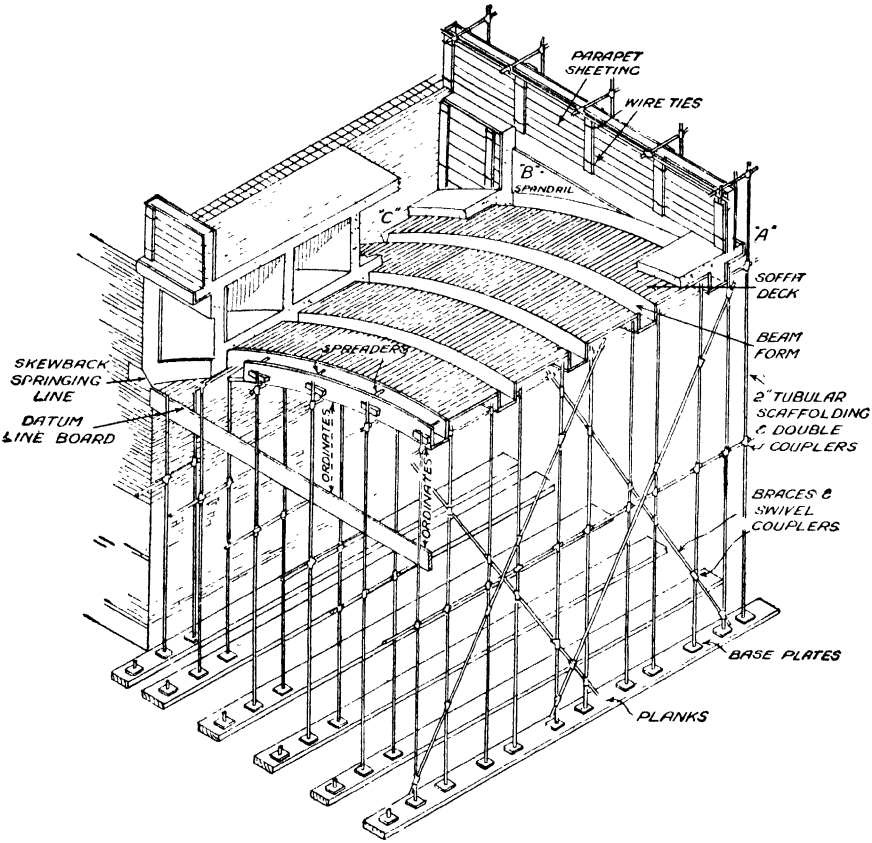


Fig. 10.—FORMWORK FOR BRIDGE

pieces of concrete) at intervals under the bottom flange ensure the correct thickness of concrete. The ledgers on which the joists rest are supported by the bearers, and lightly nailed to the sides. The decking is bevelled where it rests on the sides of the beam, and is kept back $\frac{1}{4}$ in. from the inside edge for the reason already stated. The method of supporting is shown where the floor abuts on a wall.

Bridge in Reinforced Concrete

Fig. 10 shows the general construction of the formwork for a bridge in reinforced concrete. A datum-line board is fixed at the level of the spring of the arch, and from this, ordinates are taken to the underside of the curve. Horizontal tubes are fixed at these points, and the weight per foot super to be carried will govern the number of supports required.

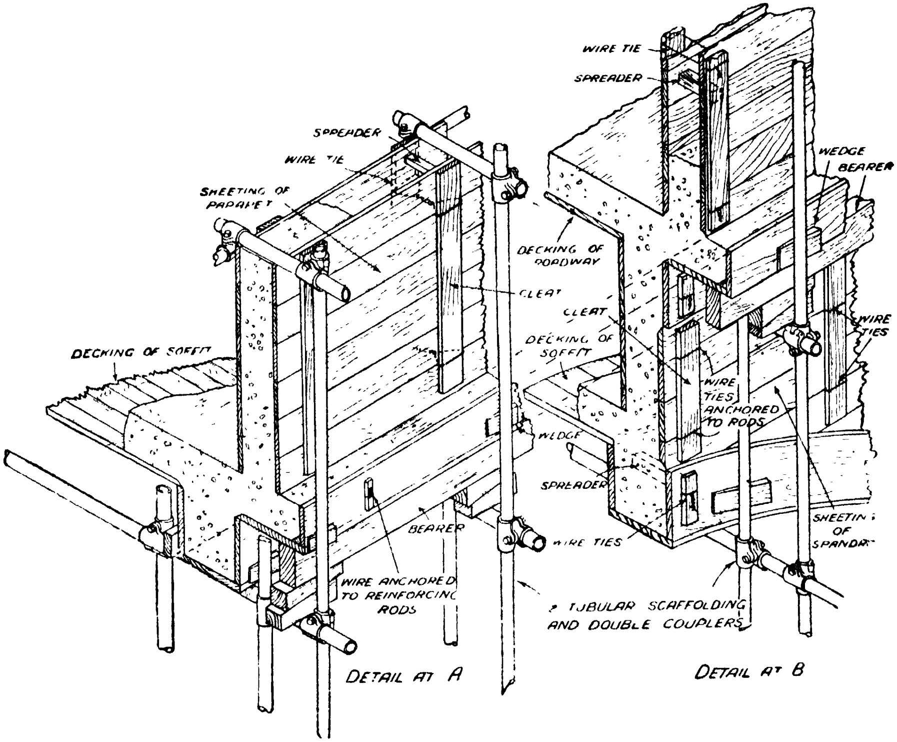


Fig. 11.—ENLARGED DETAIL OF A AND B IN FIG. 10
The top of the parapet form is stayed by securing it to a tube on the inside.

Wedges, between the sides of the beams and the top of the tube supports, keep the sides in alignment and take the pressure. Spreaders to maintain the correct width are required for the outside beams; for intermediate beams this is done by " tacking " the soffit boarding at intervals. In order that beam forms will " drop " when the stripping is done, the ends must be cut off vertical at the skewback, and a wedge-shaped portion made up to complete the curve, as shown at C.

The Top of the Parapet Form

Details at A and B are shown in Fig. 11. The top of the parapet form is stayed by securing it to a tube on the inside. The construction and details of these forms follow closely on the lines of those already described.

Metaforms

Steel forms, as illustrated and described in Figs. 12 and 13, are obtainable. Metaforms for circular work can also be supplied.

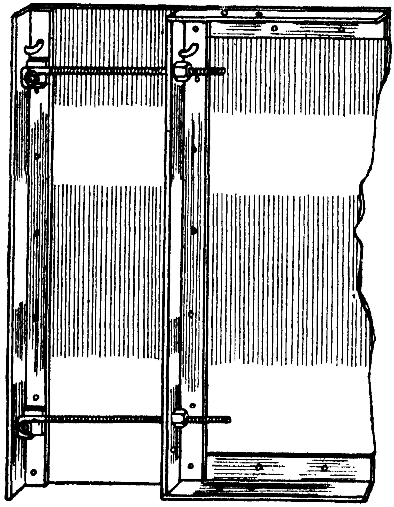


Fig. 12.—ADJUSTABLE "METAFORM" UNIT FOR CONCRETE CONSTRUCTION

The steel units are assembled into walls of required length, height, and shape, and each unit is clamped to its neighbour by unbreakable malleable clamps. These units are particularly useful for adjusting the overall length of the formwork assembly.

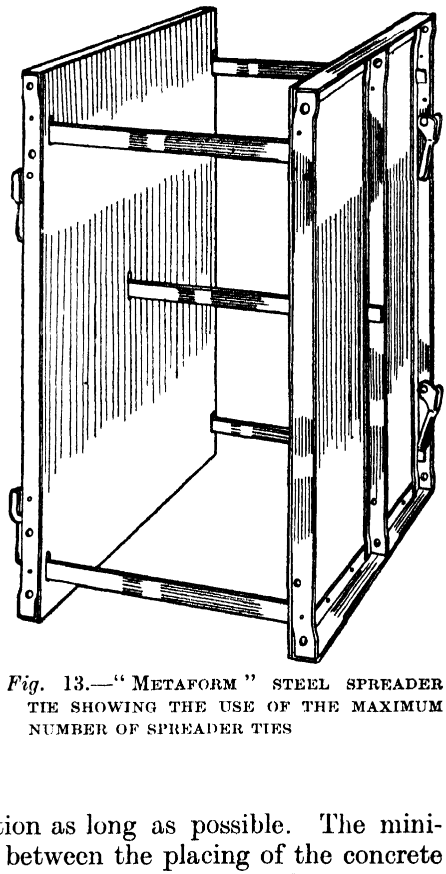


Fig. 13.—"METAFORM" STEEL SPREADER TIE SHOWING THE USE OF THE MAXIMUM NUMBER OF SPREADER TIES

Striking the Shuttering

Shuttering should be left in position as long as possible. The minimum time which should be allowed between the placing of the concrete and the striking of the forms depends upon the position in the structure, the climatic conditions, and the quality and setting-time of the cement. The minimum intervals for work done in normal weather, with a temperature of round about 60° F., will be as follows :

	Normal P.C. Concrete	*Rapid-hardening P.C. Concrete*
Beam Sides, Walls, and Columns . .	3 days	2 days
Slabs (props left under) . . .	4 ,,	3 ,,
Remove props (to slabs and beams; soffit props left under)	10 ,,	5 ,,
Remove props to beams . . .	21 ,,	10 ,,

All props must be eased slowly, and care must always be taken when striking the shuttering, so as not to jar the concrete unduly. For concrete mixed with aluminous cement, the whole of the supports can be removed after 40 hours, and with beam sides, walls, and columns, after 12 hours.

Chapter V

PRECAST WORK

THE chief factors in precast work are proper materials, good workmanship, and correct atmospheric conditions.

Obtaining a good Dense Concrete

To obtain a good dense concrete for precast concrete products, it is of great importance that the grades of the aggregates should be as near perfect as possible. Too much or insufficient sand used would result in a weaker concrete being obtained than if the grading had been perfect. For instance, with a mix of 1 : 2 : 4, viz. 1 part Portland cement, 2 parts sand, and 4 parts ⅜-in. grade to ⅛-in. ballast, it would be found that the grading of these materials is practically perfect, and when thoroughly mixed the result would be a minimum amount of voids.

The proportion of cement used with aggregates should never be too high and only on rare occasions is the mix below 1 : 2½, viz. 1 part cement, 2½ parts of sand and aggregate. All aggregates should be very clean and cubical in shape as far as possible. Very fine sand should not be used if it can be avoided.

The grade of aggregates is more or less governed by the product required. Emphasis should be placed on thoroughly mixing the cement and aggregates together before adding water.

Water should not be applied too freely. A plastic mix, thoroughly tamped and consolidated, will give good results.

For making the finest precast products, steel or cast-iron moulds are used, these being placed on a vibrating table. Tamping may be done by machine, concrete of a fairly dry consistency being fed into the mould in thin layers at a uniform rate and evenly consolidated by mechanical rammers.

Reconstructed Stone

Reconstructed stone usually has (1) a facing of a mixture of crushed natural stone (or stone dust) and cement, the mixture being gauged 3 to 1, and (2) a backing of concrete, i.e. a mixture of gravel and cement in the proportions of 4 to 1, the gravel (or granite) being screened from ¼ in. to ½ in. gauge. According to the colour or finish required, crushed Portland, Yorkshire, or whatever material may be suitable, is employed. The facing is rammed into the mould first to a thickness of 1¼ in. to 1½ in.;

the backing is then rammed in and adheres to the facing. White and cream cements are used extensively and are essential for certain colours, notably in reconstructed Portland and Bath stones. Pigments are used to colour the cement to the same shade as the aggregate to avoid a mottled effect.

Mould Making

Mould making is a very important job as far as the cast stone and concrete product manufacturers are concerned.

Any mistake in the making of the mould will be a costly job to rectify in the casting. Therefore it is essential that care should be taken to examine the mould thoroughly before dispatching to the casting shop.

Casting Face Downwards

Cast stone is being used rather extensively in these days for constructional work. Some of the moulds are rather complicated to make, but the joiner will find no difficulty once he can see in his mind the actual product for which he is about to make the mould. If a mould is to be made where the face of the casting is to be made face downwards, a good way to see clearly how the mould should be made is to turn the plan of the work upside down. A similar method can be used should the face be required on the other side of the mould, but where possible the face should always be cast downwards as this gives a better product generally.

Arrises and Recesses

Keen arrises are an important factor in the appearance of stonework and to obtain these moulds must be made with practically watertight joints. All members of the mould which have to be withdrawn from the casting must never be left square. They should be slightly bevelled to make withdrawal easy (see Fig. 1).

Fixing Slips for Making Grooves

All slips which are to form grooves, such as for instance the water drip in a sill, should be securely screwed or nailed to the main forms and truly bevelled ; nail or screw heads should be slightly sunken and the cavity filled with putty or other suitable stopping.

A Smooth Surface Necessary

Moulds should have a perfectly smooth surface, as all castings should be perfect when taken from the mould, other than dressings that are specified to be done by hand or machine.

Baseboards

The baseboards for all moulds should be made absolutely free from twist, with sufficient ledges to ensure that with continual use twist cannot happen.

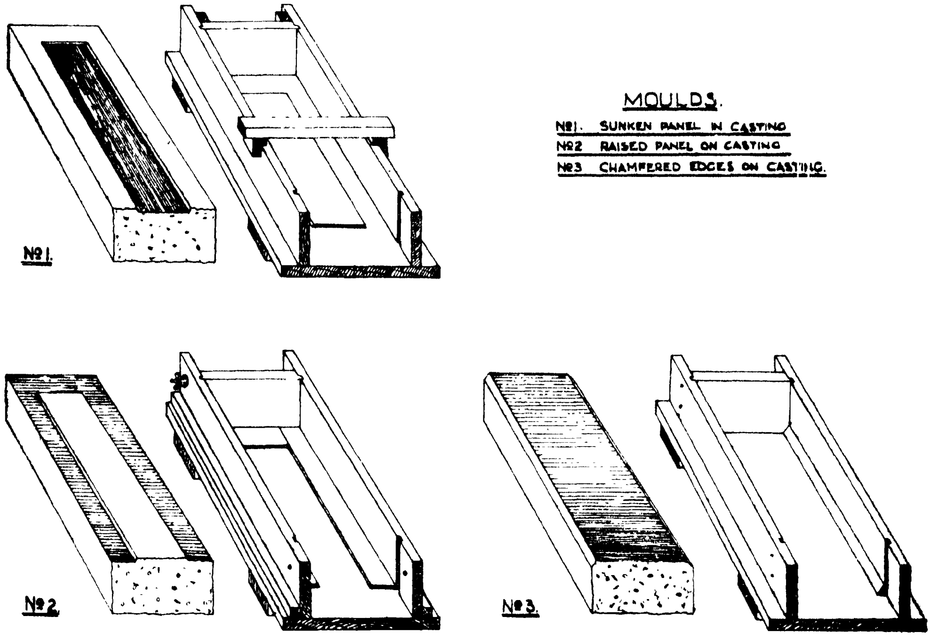


Fig. 1.—MOULDS FOR MAKING CASTINGS WITH PANELS AND CHAMFERED EDGES

Note that the panels are slightly bevelled to allow the moulds to be easily withdrawn without risk of breaking away edges of panels. The clamp shown in illustration No. 1 is used to prevent the sides of the mould from spreading when the concrete is poured into it.

Charge Mould on Level Site

Before a mould is charged care should be taken in placing the mould securely and firmly on a levelled site.

Timber Used for Moulds

The timber used for the majority of moulds is ordinary red pine, but oak or teak can be added for small members where they are liable to get damaged in the tamping process.

Soak New Mould in Water

Mould should be soaked in water before being used the first time to stop porosity, or suction will take place when the mould is charged, utilising a quantity of water which is required for the hydration of the cement. It is essential that solid-core blocks should be soaked in water whenever they get too dry, or difficulty will occur when dismantling.

Method of Framing

All moulds should be well made and designed for easy assembly and dismantling, whether it is to make one or hundreds of castings. When a

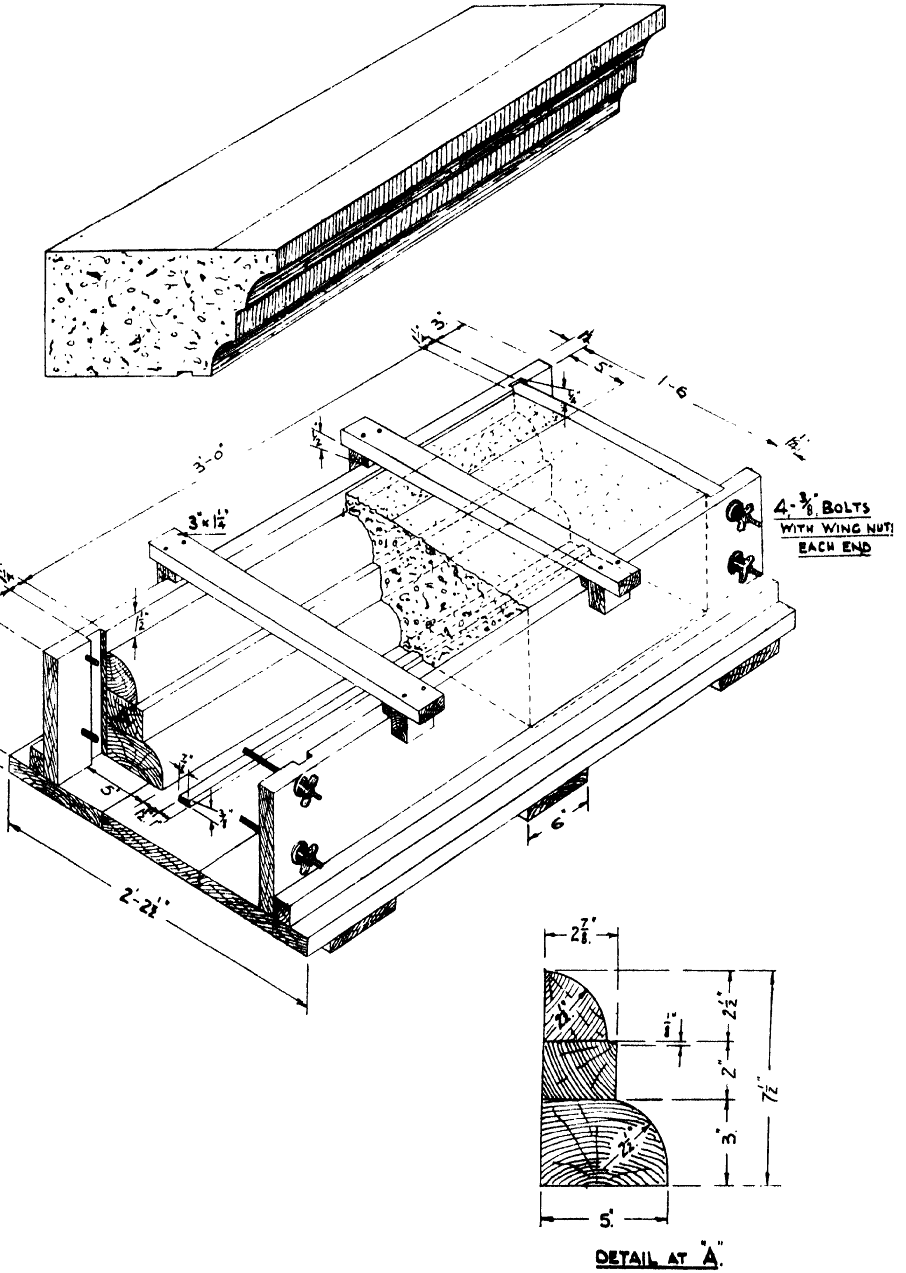


Fig. 2.—Section of concrete cornice and mould for casting it

mould is badly designed, slow production and high manufacturing costs will be the result. Time spent on making a good mould will be repaid by better products and good output. When concrete is thoroughly hard in the mould, it is easy to imagine how difficult it would be to release the members of the mould if the design for dismantling is not perfect. More often than not, when this occurs, the mould is practically rendered useless in the dismantling.

Making Dismantling Easy

Nails should never be used for fixing in position any member that has to be withdrawn when dismantling. Should it be necessary to fix, use screws, clamps, or both. Here again it is as well to remember that washers behind the heads of the screws and a little grease will assist considerably when dismantling.

Wing nuts are much more suitable for the bolt in this class of work, as generally they can be tightened sufficiently by hand. The design of mould should be such that a minimum of bolts and screws are required.

The main forms of a mould should be housed together, since it is important that moulds should be practically watertight.

Example—Constructing Mould for Cornice

Supposing a mould is required for a section of cornice 3 ft. long, 18 in. wide, and 9 in. thick, with several members and a water groove, as in Fig. 2.

The first job would be to make the baseboard. This should be made with 1¼-in. board, well ledged at either end with one intermediately. It should be free from twist.

The side forms, 1¼ in. thick, should now be worked, housing the 18-in. forms into the longer forms to the depth of ¼ in.

The long forms should be cut 3 ft. 6½ in. long, thus leaving a projection of 2 in. at either end when the box is framed.

Fixing the Forms

These projections will be sufficient to slot out for a bolt, utilising the wing nut to connect the side forms.

One bolt at either end will be sufficient, placed central of the depth of the form. It is necessary to fix two clamps across the top of the mould dividing the opening of the mould into three equal parts, these clamps should be raised 1 in. from the top of the mould by placing strips under the clamps ; this will give easy facilities for finishing off the casting ; the clamps, of course, are to stop the mould from spreading when being charged.

Having made the outer form of the mould, they can be secured to the baseboard either by screws from the underside or clamps.

The Members and How to Fix Them

The members can now be made and placed inside the forms according to the design of the cornice. Bevelled timber must be used where such is to be withdrawn from the casting, as mentioned previously. The slip for the water groove will also be fixed on the bottom of the mould since the casting will be made face downwards.

It may be found that a portion of the top of the cornice would need to be splayed to flow the water from the main building when in position. Do not cut the mould to form this as it can be formed when casting.

Preparing and Cleaning Moulds

Moulds should be carefully cleaned immediately the casting is taken from them. Once, however, cement or other loose material is allowed to adhere to the mould for any length of time, the mould will become more or less ruined.

To Prevent Wood Absorbing Water

It is quite a good plan to treat the mould with shellac, especially when end-grain wood is left exposed, as this will prevent a great deal of absorption.

To Prevent Concrete Sticking to Mould

Precaution must be taken to prevent concrete adhering to the mould. There are many kinds of mould oils on the market for this purpose which will not discolour the concrete. A satisfactory oil is made of 75 per cent. of paraffin and 25 per cent. of raw linseed oil thoroughly mixed.

After cleaning, the mould should be thoroughly oiled about 10 minutes before using ; the oil should be applied fairly thinly as too much is detrimental to the setting properties of concrete.

Storing away Moulds

When a mould has made the amount of castings required and is still in good condition it should not be destroyed, but carefully put away in dry store, as it often happens that moulds can be converted quite easily, therefore saving time and labour.

Moulds Lined with Zinc

Some manufacturers prefer to have the main forms of a mould lined with zinc or galvanised-iron sheeting, which, of course, lengthens the life of the mould.

This method is very effective for moulds that are in continual use making repeat products.

Curing Concrete

Hardening of concrete is due to a chemical action set up between cement and water. Therefore it is necessary to keep the concrete more

or less damp for several days after being made. If the concrete is allowed to dry out too quickly, it will be more or less perished, and in cases where the product is rather fragile it would soon begin to decay.

To Avoid Concrete Drying too Quickly

All concrete work should be shielded against drying winds and the sun, especially during the summer months. Of course, in some cases it is practically impossible to carry out these precautions, but when making products in the yard or shop it can generally be arranged.

After Removing Casting from Mould

When the casting is taken from the mould, say, twenty-four hours after being made, it is quite a good plan to cover the casting with clean damp sand for at least one week or keep the casting sprayed with water three times per day and cover with hessian cloth or other suitable light materials.

Casting in Frosty Weather

Great care must be taken when casting in frosty weather, and should the aggregate be frozen (as it often is during the winter months) it should not be used until thawed with either heat or warm water.

All new work should be thoroughly covered during frosty weather.

Care in Applying Mould Oils

All mould oils should never be applied too freely. It should be remembered that the application of these oils is only necessary to prevent the concrete from adhering to the mould. Therefore the thinnest coat possible only is required. Some mould oils are known to stain and even retard the setting powers of cement if applied too thickly. As mentioned before, 75 per cent. of paraffin and 25 per cent. of raw linseed oil mixed together will give excellent results for oiling moulds.

MAKING CONCRETE PRODUCTS IN A MOULD BOX

The purpose of the next section is to show and explain how simple it is to make many types of concrete products in a mould box. There are of course many hand-working machines on the market for such work, but one cannot always bear the costs of such machines, especially when a limited number of products are required.

The box as shown is quite simple to make, and its cost would be within the limit of many small manufacturers.

General Description of Box

The mould box is housed and screwed together at two opposite angles with a mitred joint at the angle where hinged, while the remaining angle is a butt joint to receive the fastening (see Fig. 3).

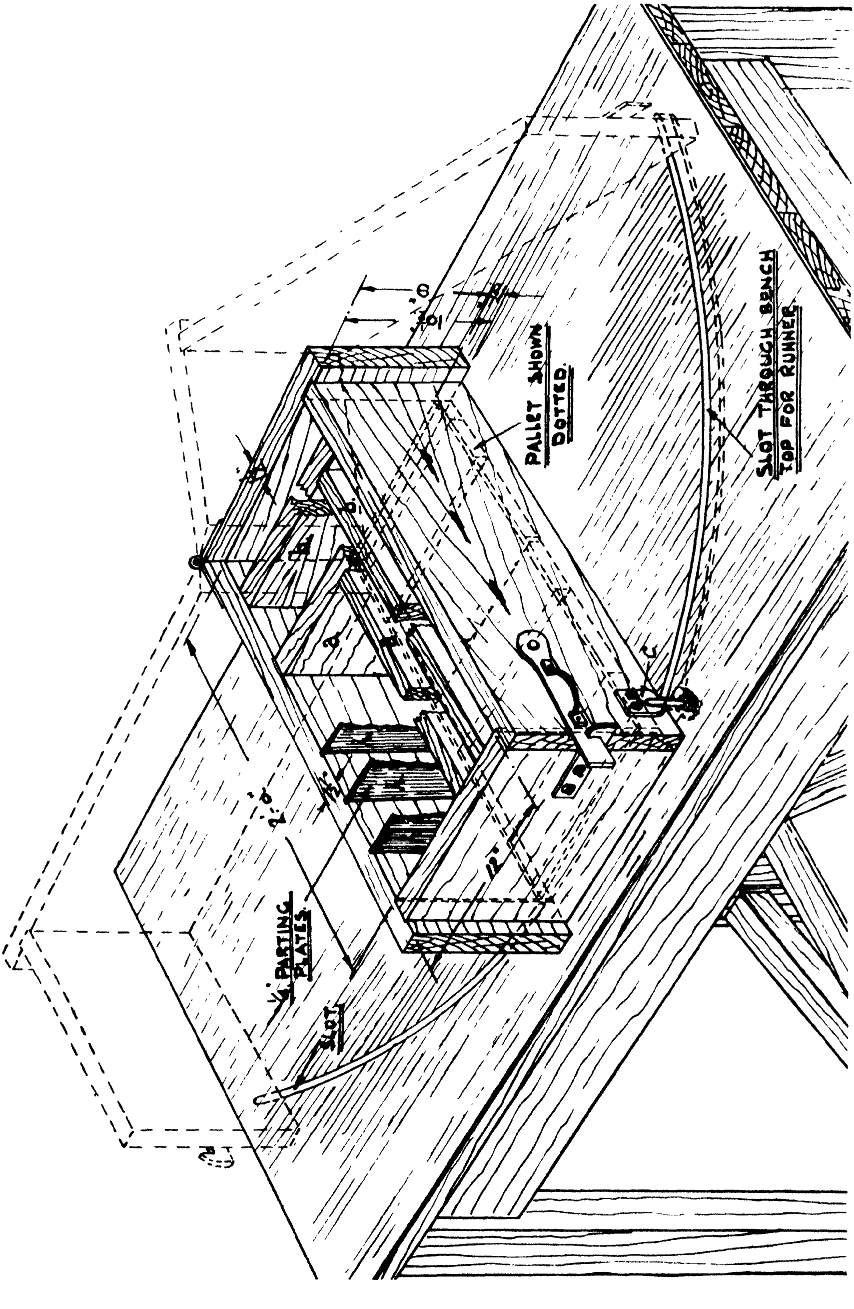


Fig. 3.—Mould box assembled on bench

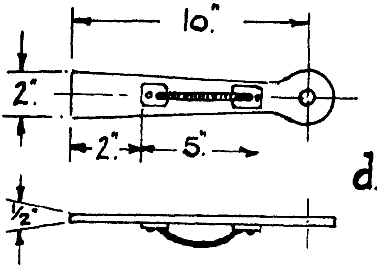


Fig. 4.—Detail of mild-steel latch for mould box

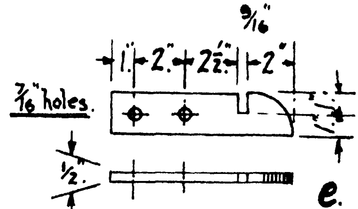


Fig. 5.—Detail of mild-steel latch housing for mould box

The hinge is bolted to the box, the centre pin of which is a bolt long enough to pass through the table top and fitted with nut and washer on the underside.

Runners and Fastening

The runners should be as to dimensions given and bolted to the sides of the mould box.

All bolt heads should be sunken flush with the inside of the mould. As will be seen, these runners travel in a slot formed in the top of the bench, therefore keeping the sides of the mould in position when released.

The fastening is an ordinary affair which is quite suitable for the job.

Size of Mould

The inside dimensions of the mould are 2 ft. by 1 ft. by $10\frac{1}{2}$ in., thus allowing for the

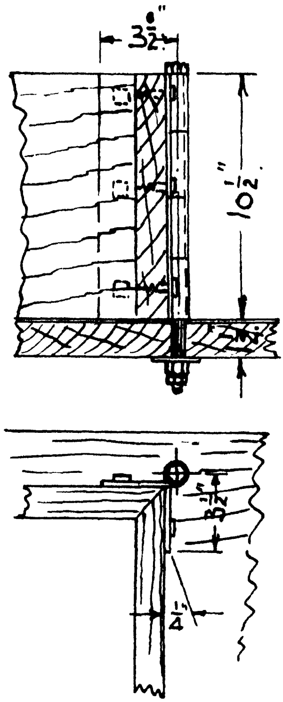


Fig. 6.—Detail of hinge for mould box

Note bolt fitted through bench top.

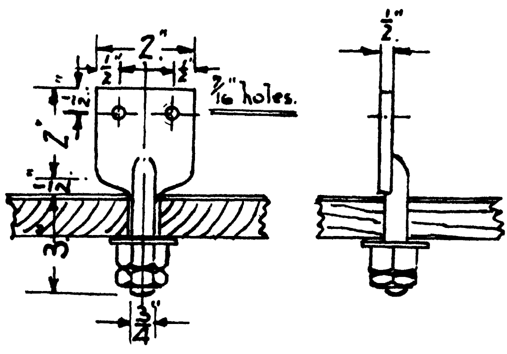


Fig. 7.—Detail of runners for mould box

These fit in slots in bench as shown at *c*, Fig. 3.

pallet to be made up $1\frac{1}{2}$ in. thick; therefore when the pallet is in position the depth of the mould is 9 in.

Bench

The bench need not be elaborately made, strength being the chief factor.

A suitable size would be 3 ft. 6 in. long, 2 ft. 6 in. wide, and 2 ft. 6 in. high. The top should be covered with thin mild-steel sheeting of No. 14 S.W.G.

Pallets

The pallet is the board upon which the product would be made and carried away to mature.

It is placed inside the mould box before commencing to fill, as shown in Fig. 3 with dotted lines.

Each product must be made on a pallet, since it is necessary for such to remain on the pallet for twenty-four hours before being sufficiently hard to remove. The pallet should be made of 1-in. board and ledged with three $\frac{1}{2}$-in.-thick strips placed at either end, with one intermediate.

Timber to Use

Ordinary deal timber can be utilised for all the parts.

The mould box could be ledged on the outside should it be necessary, this, of course, being governed by the quality of timber used. To give long life to the box, zinc lining could be used on the inside and top edges if a large number of products are to be made.

To Make Bricks in Mould Box

The mould can be converted to make bricks by inserting $\frac{1}{4}$-in. divisional plates as shown at *h*, Fig. 3. These plates would be withdrawn immediately the bricks were made.

Having a fair-size mould box it will be seen how easily many different-size blocks can be made by simply inserting various distance strips, such as *a* and *b*, Fig. 3, to suit requirements.

Small precast paving slabs can easily be made and, if sufficient care is taken to prepare a sketch of the lay-out before attempting to cast, such products can be made to fit accurately.

Mix of Concrete

It should be remembered that the consistency of mix for products proposed to be made in this type of mould box must be semi-dry. That is to say, only sufficient water must be added to allow the mix to " ball " as it were when a handful is squeezed tightly.

This, of course, will allow the product to be released from the mould immediately.

Curing

The curing of products made on the semi-dry principle must be carefully carried out. They should be placed free from the sun and drying winds immediately when taken from the mould and watered after twenty-four hours three or four times each day for seven days. The castings can be taken off the pallet twenty-four hours after being made and laid openly until they are finally matured by the foregoing process.

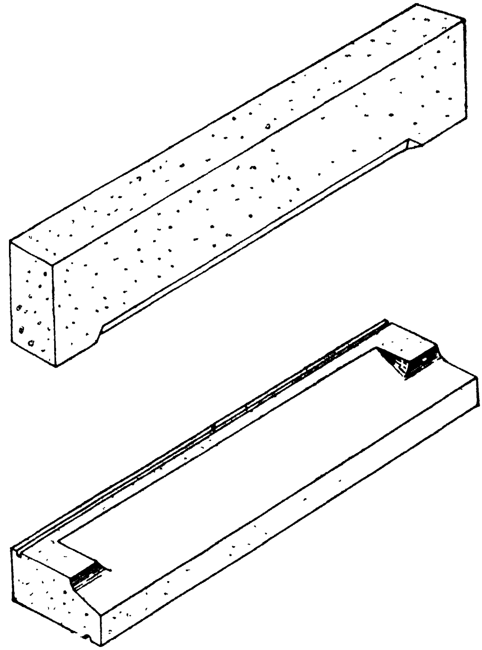


Fig. 8.—CONCRETE WINDOW SILL AND HEAD

CONCRETE WINDOW SILL AND HEAD

There are many designs for window sills and heads, but those shown in Fig. 8 are perhaps the main ones used to-day. These are for the ordinary type of window for the six-roomed house. It will be seen that the moulds for both are designed in order to cast them face down.

Head Mould

This [mould is quite a simple affair: just a box formed with a bevelled strip fixed on one side at the bottom of the mould. This bevelled strip will form the chamfer on the casting, as shown.

Sill Mould

This type of mould should be made fairly strong with stout timber and housed as mentioned previously. Such moulds are generally required to make large quantities with the least possible maintenance charges, therefore it is essential to make them as strong as possible.

The strip to form the water-bar groove should be made of a piece of hardwood or iron and made to fit easily in a groove at the bottom of the mould, as shown, so that it can be easily withdrawn before the mould is dismantled (Fig. 10).

This is a good method to form a clean groove for the water bar.

The wood members for forming the weathering slope and stooling should be securely screwed to the baseboard.

Ordinary deal is quite suitable for these moulds.

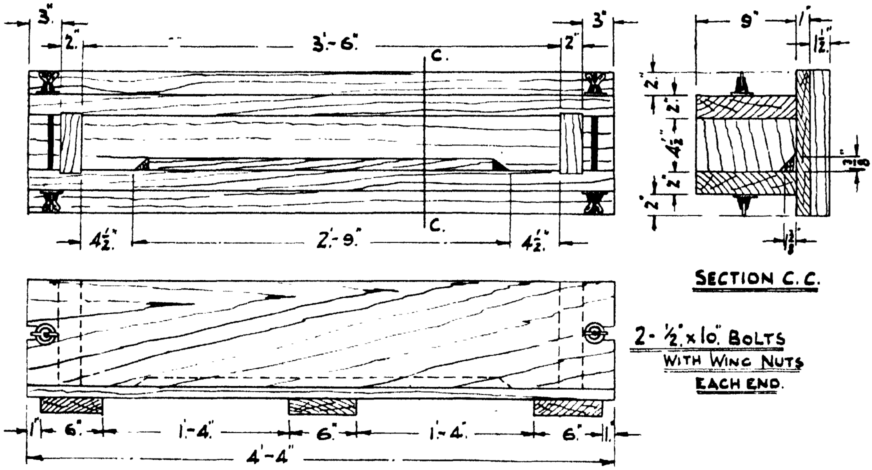


Fig. 9.—Mould for window head

This is simply a box with bevelled strip attached.

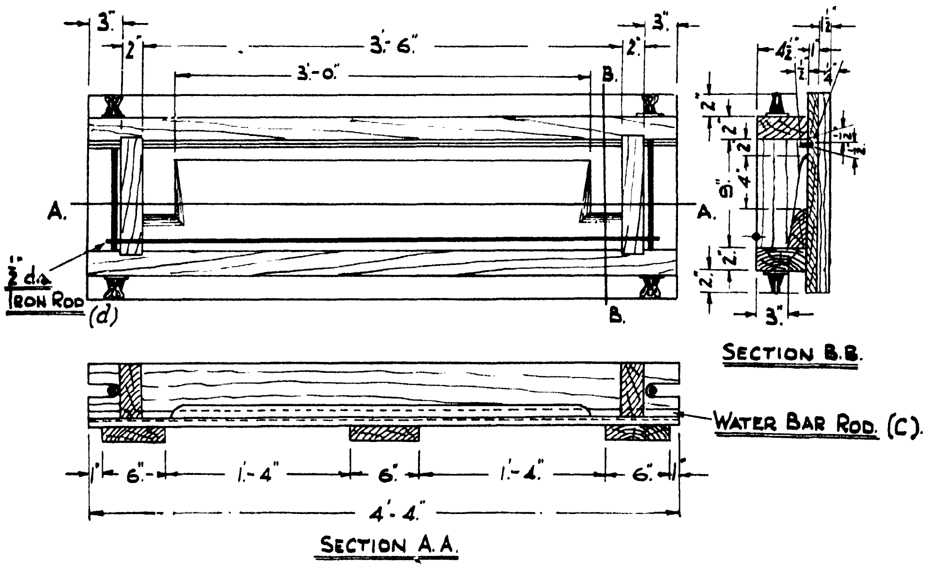


Fig. 10.—Mould for window sill

Note the hardwood strip to form the water-bar groove. Both head and sill moulds are cast face downwards.

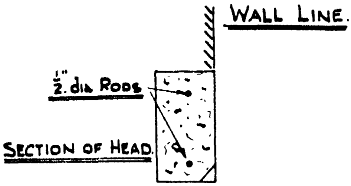


Fig. 11.—SECTION OF CONCRETE WINDOW HEAD SHOWN IN POSITION

Note the two mild-steel rod reinforcements.

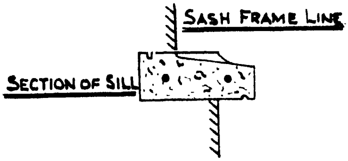


Fig. 12.—WINDOW SILL IN POSITION

The sill is also reinforced with two mild-steel rods.

Both moulds must be turned upside down to dismantle.

Release the baseboard and withdraw carefully before releasing the side forms.

Mix of Concrete

The proportions of aggregates for concrete work in general is very important, and for this work obviously the aggregates should not be too large.

The following proportions should give satisfactory results: 3 parts ¼-in. to ⅛-in. ballast, 1½ parts clean washed sand, and 1 part Portland cement.

Placing the Concrete

The mix should never be too sloppy, therefore it is essential thoroughly to consolidate the concrete to obtain a good casting.

Slow feeding with good tamping is the main factor.

When the moulds are completely filled they should be screeded off and, in the case of the sill mould, the drip should be formed with the aid of a ½-in. round iron bar as shown in Fig. 10.

Curing

Like other concrete products, heads and sills require curing. They should not be taken from the mould under three days, following which they should be kept damp and covered with either cloth or clean sand for a further seven days before allowing to finally dry out.

Reinforcement

Both the head and sill should be reinforced with two ½-in. diameter mild-steel rods hooked at either end and placed as shown in Figs. 11 and 12.

MAKING A CONCRETE DOORWAY

The doorway shown in Figs. 13 and 14 is designed to marry with brickwork or any other type of walling. The jamb and head stones are

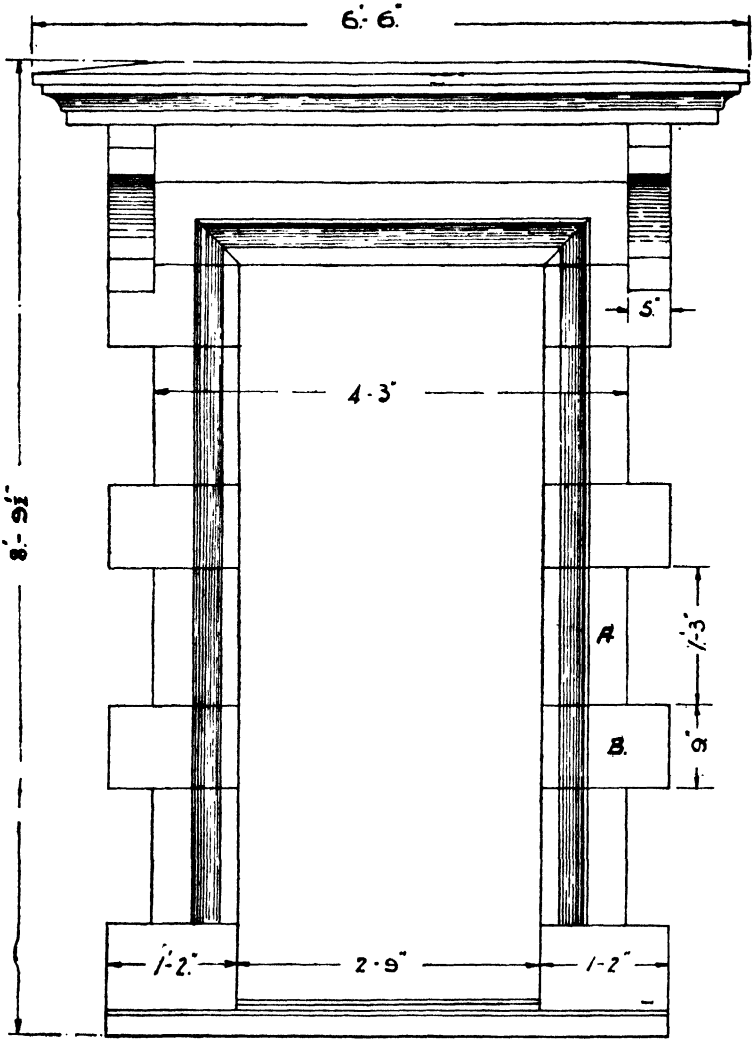


Fig. 13.—CONCRETE DOORWAY

A section is shown on the opposite page, and the moulds needed to construct the various parts are illustrated in Figs. 15 to 18.

rebated to take the door frame, and with the canopy and threshold having a fair projection the entrance should look rather bold and pleasing. As will be seen from the drawing, the canopy is supported with corbel stones. These should be made deep enough to allow them to be fixed in the walling.

The moulds for the corbel stones, jambs, base stones, and the stone

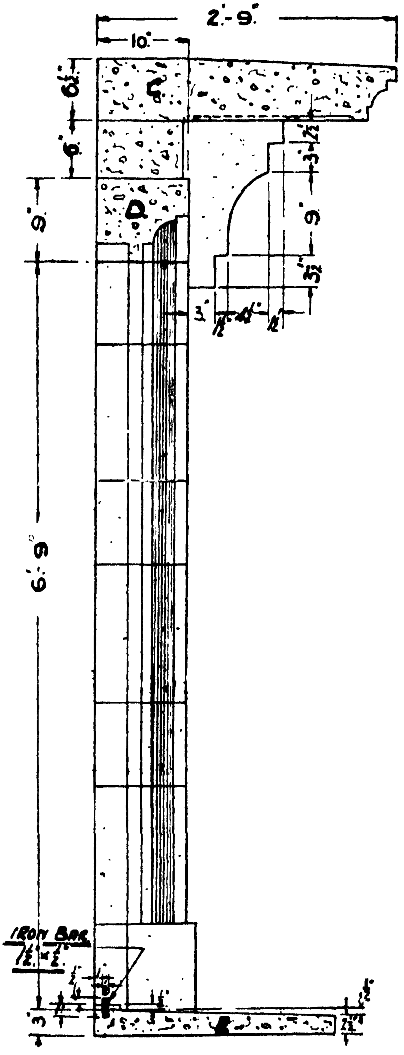


Fig. 14.—Section through concrete doorway

between the door head and canopy, are not shown as these are quite plain and should not require any explanation.

Mould for Canopy

The canopy mould should be made on the strong side, since the casting will be rather heavy. The false bottom will form a sunken panel on the underside of the casting. It should be cut out as shown to form a stooling for the corbel stones and well chamfered on all edges. These members, which form the moulding, should be worked clean and cut true at the mitred joint.

The dotted lines in section DD indicate the bevelled top which is necessary to throw the water from the main building. This can be formed with a screed when completing the casting.

The mould and casting must be turned upside down to dismantle. Having done this, the baseboard should be withdrawn, followed by carefully releasing the side forms.

Mould for Threshold

The mould for the threshold is fairly plain work, the bottom of which is raised and tapered to form the necessary gradual fall from back to front.

The iron bar, as shown, must be placed in the mould before filling, as this should be in the casting when released. It will be necessary to plough the bottom of the mould to receive this bar; the groove must be slightly wider than the bar to allow for easy withdrawal.

The dismantling of this mould should be carried out in the same manner as that for the canopy.

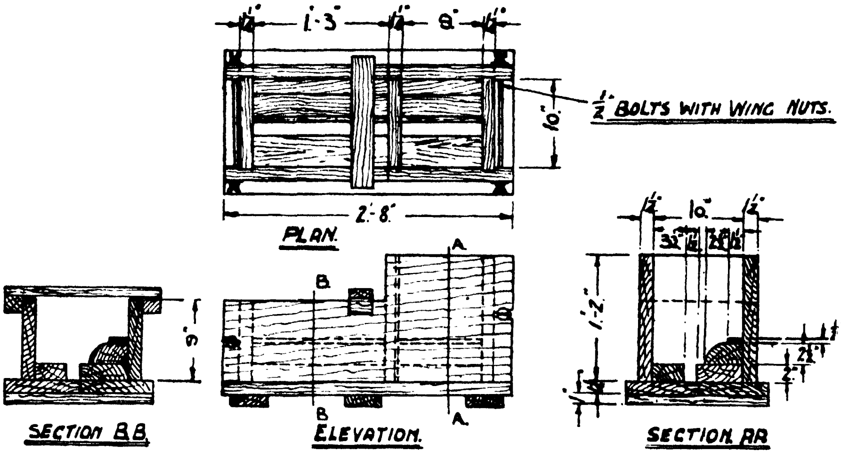


Fig. 15.—Mould for blocks A and B of concrete doorway

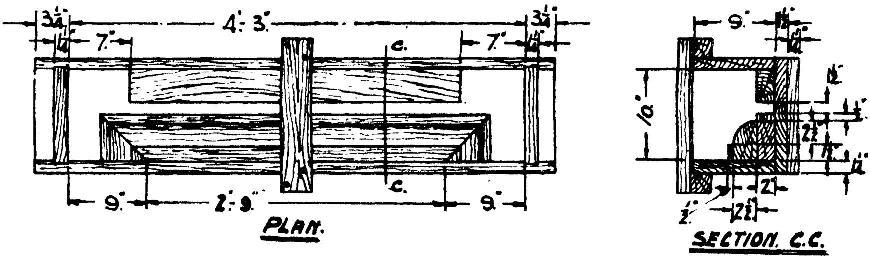


Fig. 16.—Mould for head D of concrete doorway

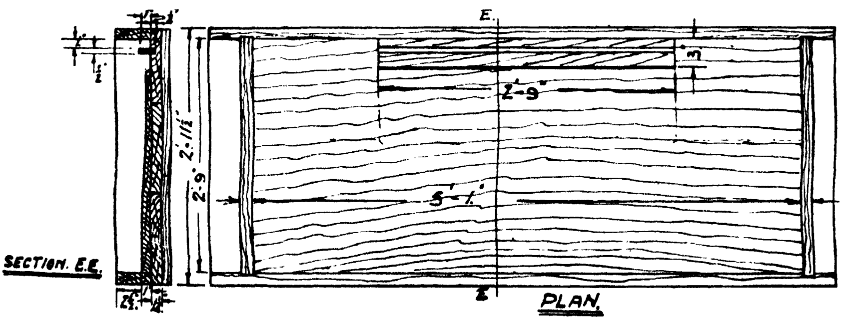


Fig. 17.—Mould for threshold E of concrete doorway

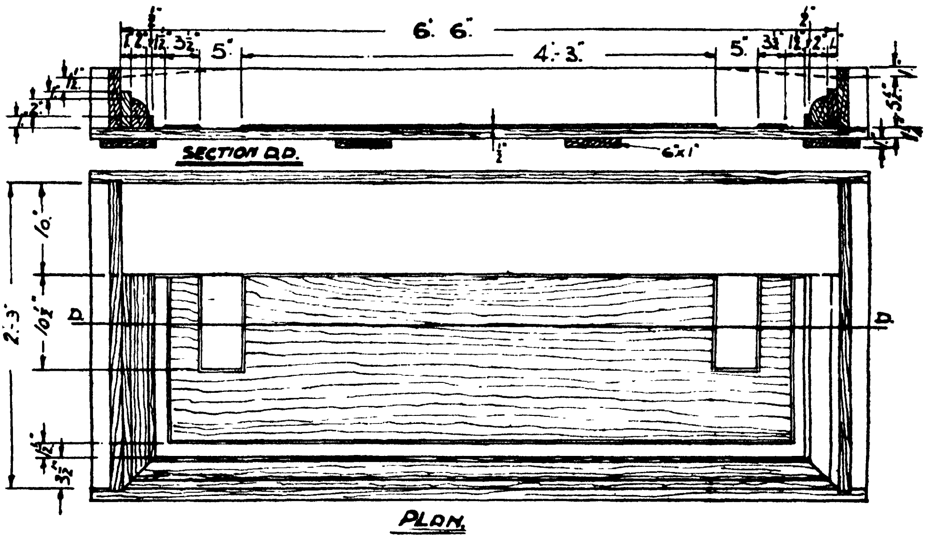


Fig. 18.- MOULD FOR CANOPY C OF CONCRETE DOORWAY

Mould for Head

As is clearly shown, these moulds are made with the face side downwards, since it is recognised that better results are obtained in this manner.

For this particular mould there is not much detail, providing the dimensions given are worked to. It is necessary, of course, to work the members clean, since the result of the casting is more or less governed by the shape of the mould as far as appearance is concerned.

Moulds for Blocks A and B

This mould is designed for both size blocks A and B to be made in the one mould.

The members which form the moulded face are, of course, similar to those for the head ; therefore, it is necessary to work them all at the same time to ensure each detail is correct.

This mould, and the head mould, should be turned upside down to dismantle and stripped in a similar manner as already described.

Aggregates

If a natural stone appearance is required, it is necessary to use natural stone as aggregate.

For instance, should Portland stone be the desired appearance, it would be necessary to use three parts of $\frac{3}{8}$ in. to $\frac{1}{8}$ in. Portland stone, $1\frac{1}{2}$ parts Portland stone dust $\frac{1}{16}$ in. downwards, 75 per cent. ordinary Portland cement, and 25 per cent. white cement.

Reinforcements

The canopy should be reinforced with four ½-in. diameter mild-steel bars, hooked at either end, and tied to 4-in. mesh expanded metal. The expanded metal should be cut within 2 in. of all sides of the mould and placed central. The bars should be spaced equal distances running across the mould from front to back.

The head should contain three ½-in. diameter bars.

PRECAST CONCRETE STEPS

The design of moulds in the following section is for the more artistic type of precast steps which are so extensively used in public buildings, hotels, etc.

Such moulds are rather expensive to make, but of course many castings can be made from each mould. Therefore, if the cost of the mould is spread over the quantity of castings produced, it will be found that the cost of mould per casting is a very low figure.

Designing the Steps

The mould for the first tread is so arranged as to make both ends circular. Of course, if the run of steps is to be carried on one side by a party wall, only one end would be circular. Likewise, the remaining treads would show the return nosing only at one end. Should the steps be open on either side when erected, they would obviously be made with the returns at either end.

Making the Moulds

It is essential for the moulds to be made perfect for this class of work, since the castings produced invariably are required to be polished and finished off to show perfect details. It is obvious that if the moulds are

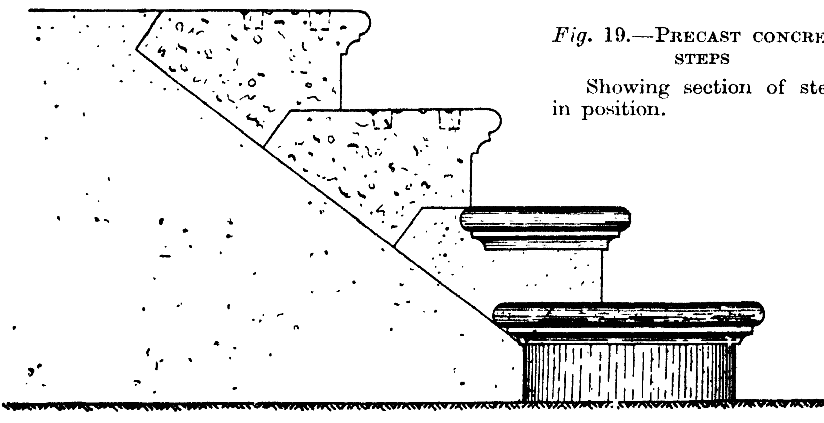


Fig. 19.—PRECAST CONCRETE STEPS

Showing section of steps in position.

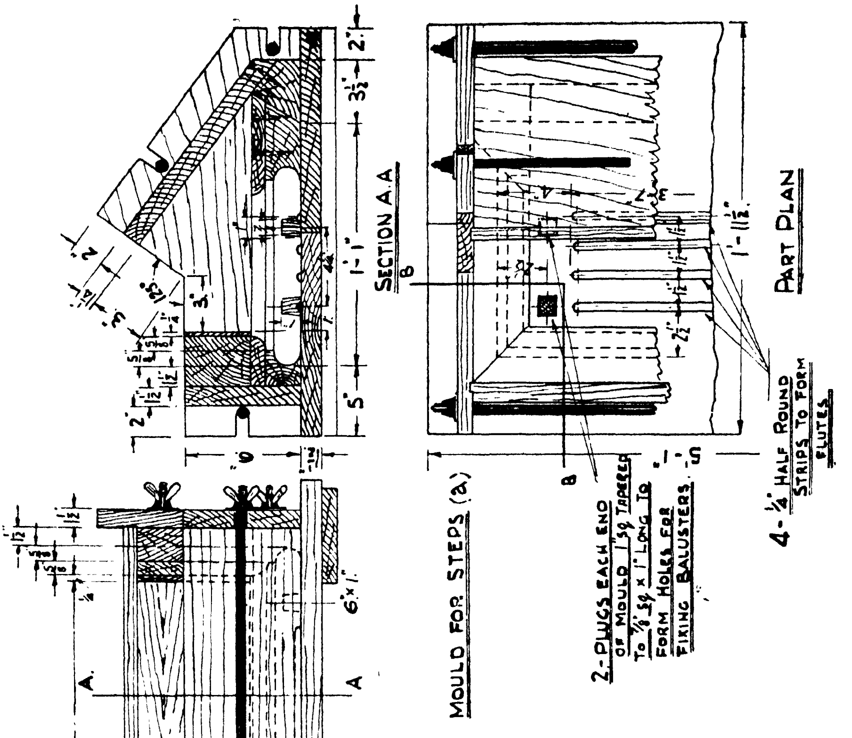
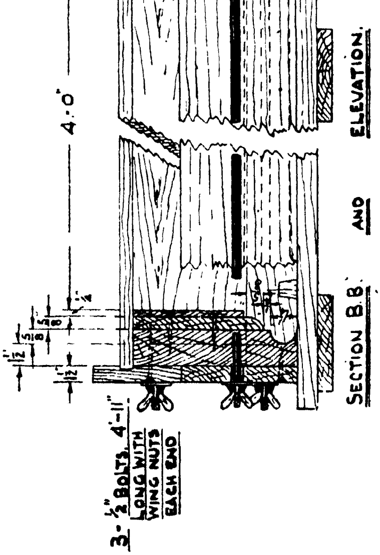



Fig. 20.—MOULD FOR STEPS

not made perfect, much time and labour must be spent on the castings.

As will be seen from the drawings, the moulds should be formed for the castings to be made face downwards, utilising bolts with wing nuts to hold the forms rigid.

All joints should be housed together where possible, to ensure they are more or less watertight.

For Fixing the Balusters

Tapered wooden plugs should be fixed to the baseboards, where shown, to form holes for fixing balusters.

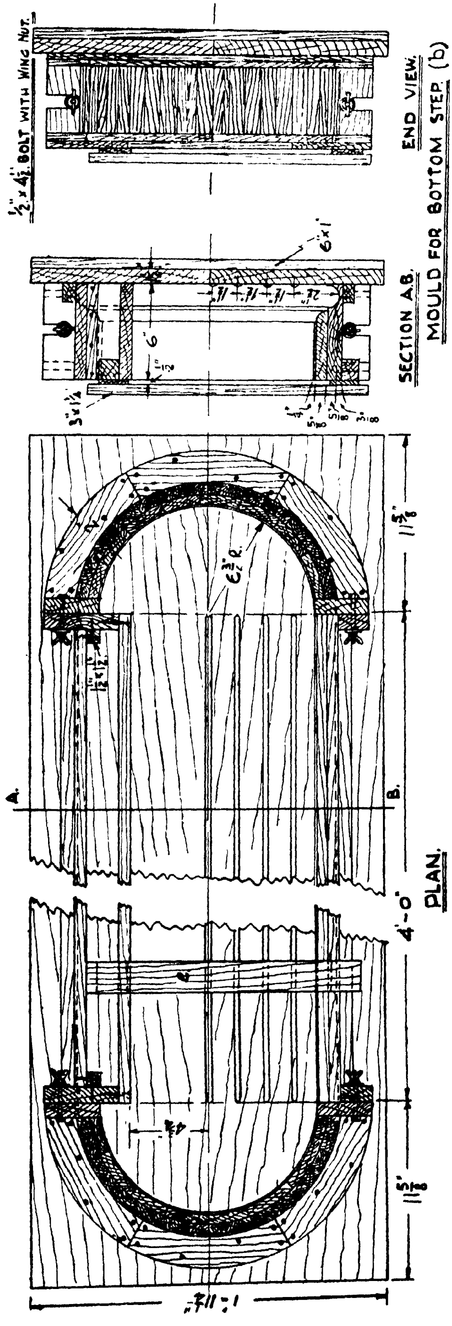


Fig. 21.—Mould for Bottom Step

Hardwood or iron ¼-in. half-round strips should also be securely fixed to the baseboards to form flutes in the top of the treads.

Moulded Nosings

As will be seen from the drawings, the moulded nosings can be so formed by working separate thicknesses of wood finally screwed together as one block. Of course, wherever possible they can be worked in the solid.

The moulds must be made absolutely free from twist; therefore the baseboards should be very carefully made.

Timber

Selected red deal is suitable for the greater portions of these moulds—shakes, of course, being avoided. The plugs and half-round strips should be in hardwood or iron.

Dismantling Moulds

To dismantle, the moulds must be turned upside down. The baseboard should be gently tapped before withdrawing. This method will more or less free the plugs and strips. The side forms should be evenly and carefully withdrawn to ensure against broken arrises.

Treatment of Moulds

All moulds should be treated before casting to prevent the concrete adhering to the forms. For this particular job, it is as well to shellac the finer members, if not all the mould. Follow this with an even coat of paraffin and raw linseed oil.

Mix of Concrete

The aggregates for such work will depend upon the type of finish required. If polished work is to be the finish, then marble, speckled granite, or other suitable stone for polishing must be used, but for unpolished work, grey granite should be used.

The proportions should be $2\frac{1}{2}$ parts $\frac{3}{8}$-in. to $\frac{1}{8}$-in. marble or granite, $1\frac{1}{4}$ parts $\frac{1}{8}$-in. to dust, and 1 part cement, either coloured or ordinary.

The mixing of these aggregates and cement must be carefully carried out, care being taken not to use the water too freely as a stiff, plastic mix is required.

Placing the Concrete

The concrete should be carefully placed and thoroughly consolidated, especially on the bottom and sides of the mould. Some steps are required to show a carborundum face, and to obtain this either the carborundum can be sprinkled over the bottom of the mould in its dry state before the filling commences, or it can be mixed with the first small batch of concrete.

Curing

The castings should remain in the moulds four days from the time of being filled, and when taken from the moulds they should be kept damp and covered for a further seven days before polishing, if that is to be the finish.

Finishing Castings

When the castings are sufficiently hard, say, seven days from the dismantling, they can be lightly rubbed with a carborundum stone and finally finished with a snake stone, utilising plenty of water during the rubbing process. This will give a fairly good polished surface. Of course, there are several types of machines on the market for this class of work.

Reinforcement

It is not necessary to reinforce the steps as described above as far as strength is concerned. But such products are subject to being bumped about in transit, therefore it is better to be on the safe side. Three $\frac{1}{2}$-in. diameter mild-steel bars hooked at either end, spaced at equal distances and central, will ensure against transit breakages.

CIRCULAR WORK

Timber for Circular Forms

Timber for making circular forms should be more carefully selected than that for straight work, since it is very important to keep these free from twist to ensure a good job.

The ribs should be 2 in. thick, while the lagging should not be too wide, 1 in. being most suitable, but, of course, the width should be governed more or less by the curvated segment.

Circular moulds are always interesting to make, but care must be taken in the setting out. Take for instance a mould for a circular tank, **3** ft. in diameter (see Fig. 22).

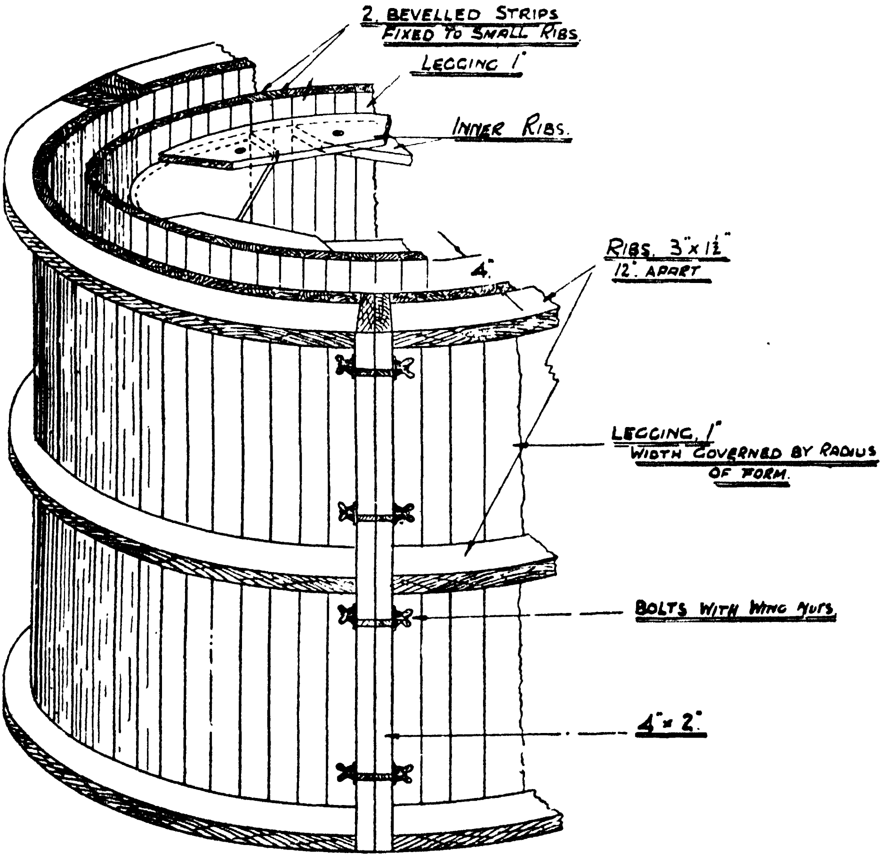


Fig. 22.—METHOD OF ERECTING CIRCULAR FORMS

Note the strong construction, with ribs both inside and outside the forms, and not more than 12 in. apart. The principles of construction are the same whether the forms are for making a concrete tank, water tower, or stack. Ease of dismantling is again a subject for forethought, as it should be whenever forms are being put together.

The outer forms should be made in three segments while the inner forms should be in six segments, three of which are small with four pieces of lagging attached to the ribs for each segment.

These small segments should be slightly bevelled inwardly on either side. When assembling the mould they should be placed alternately to the larger segments and fixed together with either bolts or clamps. When dismantling it will be found that the small segments can be withdrawn quite easily, leaving the larger segments absolutely free.

The outer forms would, of course, also be either clamped or bolted, but there would be no difficulty in dismantling these.

Chapter VI

CONCRETE PATHS AND GARDEN STEPS

CONCRETE PATHS AND EDGING

A GOOD effect of crazy paving can be obtained with *in situ* concrete as shown in section A of Fig. 1, while section B shows a smooth type of finish.

This illustration is for a footpath 3 ft. wide.

Assembly of Forms

The side forms are battens 3 in. by $1\frac{1}{2}$ in. fixed securely by wooden stumps (*d*) driven into the ground and nailed to the forms.

Screed Batten

The screed batten (C) should be 4 in. by $1\frac{1}{4}$ in., and if a slight camber is required on the path this can easily be formed by shaping

Fig. 2.—CONCRETE PATH EDGING

The mould for making this is illustrated in Fig. 3.

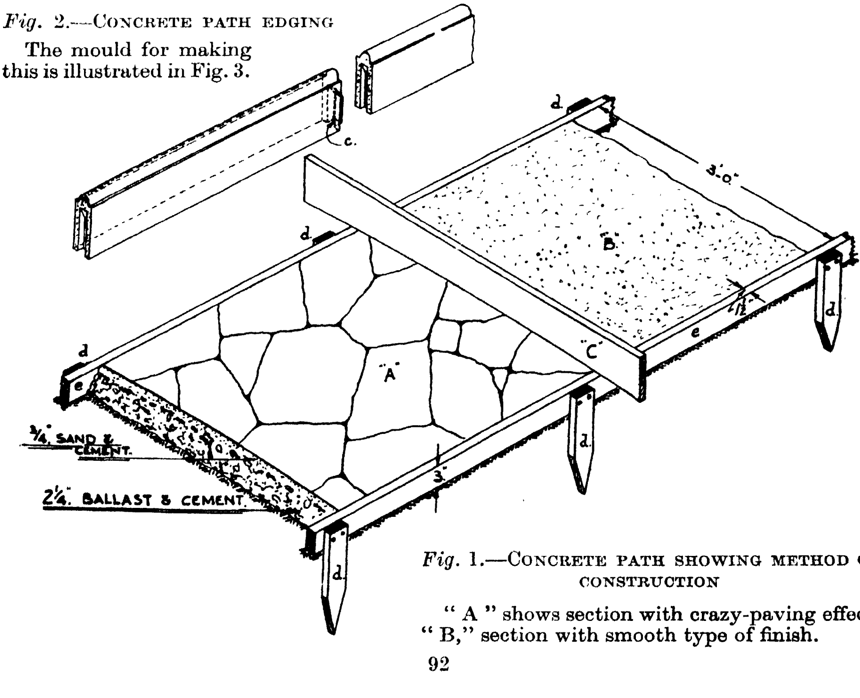


Fig. 1.—CONCRETE PATH SHOWING METHOD OF CONSTRUCTION

" A " shows section with crazy-paving effect.
" B," section with smooth type of finish.

the bottom edge of the screed batten to the desired depth of the camber.

The camber for a path 3 ft. wide should not be more than $\frac{1}{2}$ in.

Preparation of Foundation

Providing the subsoil is fairly hard no hardcore is required for the foundation, but a fairly true base is required to give even thickness of concrete, and this can be made as such with a coating of 1 in., or thereabout, of breeze lightly rolled.

Before laying the concrete this breeze should be watered.

Thickness of Concrete

The concrete should be laid 3 in. thick in two-coat work as shown, viz. $2\frac{1}{4}$ in. of ballast concrete and $\frac{3}{4}$ in. of sand and cement.

Method of Construction

Although the concrete is laid in two-coat work, the finishing coat of sand and cement must follow the laying of the ballast concrete within half an hour to ensure an homogeneous concrete ; therefore, it is necessary to mix the two separate batches of concrete before commencing to lay, and if the job is carried out in hot weather or a strong drying wind the sand and cement batch should be covered with damp sacking or other suitable material.

Each batch of concrete should not be more than is required to cover a 12-ft. length of path, unless, of course, sufficient labour is at hand to cope with the material. A good plan for this type of work is to lay one bay, leave the second bay and lay the third, and so on, which is commonly known as the alternate bay system.

The ballast concrete should be well consolidated and maintained evenly throughout, leaving the $\frac{3}{4}$-in. depth for the top layer. This can be so worked by using a recessed screed. The sand and cement coating will be finished evenly with screed (C).

Expansion Joint

Since concrete expands and contracts, it is necessary to allow for this by using some kind of more or less elastic material. For this type of work a strip of wood $\frac{1}{4}$ in. thick or bitumen damp-course material should be utilised at 12-ft. intervals.

Crazy-paving Effects

When the finishing coat has had sufficient time to settle, say, one hour after being laid, the crazy-paving effect can be obtained by marking lines to the desired depth with $\frac{1}{2}$-in. diameter bar of iron or wood.

It is quite easy to get to the depth of the finishing coat.

When the concrete is sufficiently hard rough edges can be removed by passing a soft-haired broom gently over the surface of the concrete.

Mix of Concrete

The proportions of mix for the bottom coat should be 4 parts of ½-in. grade ballast, 2 parts of clean sharp sand, and 1 part Portland cement, while the top coat should be 3 parts clean washed sand and 1 part Portland cement. Coloured cement can be obtained if so desired.

Mould for Path Edging

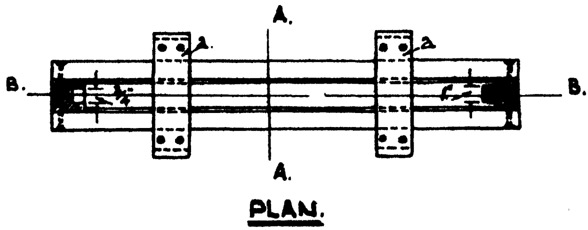
The design of mould for path edging is such as to give each length of casting an intersecting joint at " c," Fig. 2, and to be made face downwards.

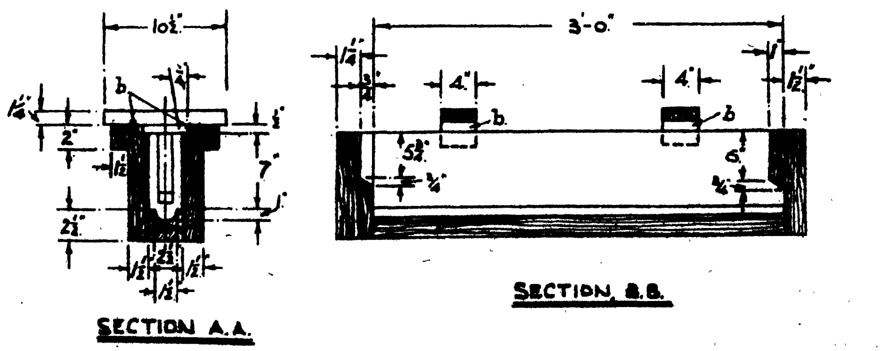
Ordinary red deal wood free from dead knots and big shakes is quite suitable for this mould.

All the forms should be true to shape and worked to a smooth surface and keen edges. The side forms can be either screwed or clamped to the ends and bottom members with two top clamps at (*a*), Fig. 3, to ensure against the mould spreading.

Fig. 3.—MOULD FOR CONCRETE PATH EDGING

The completed casting can be seen in Fig. 2. All forms should have a smooth surface and keen edges. The edging is cast upside down.





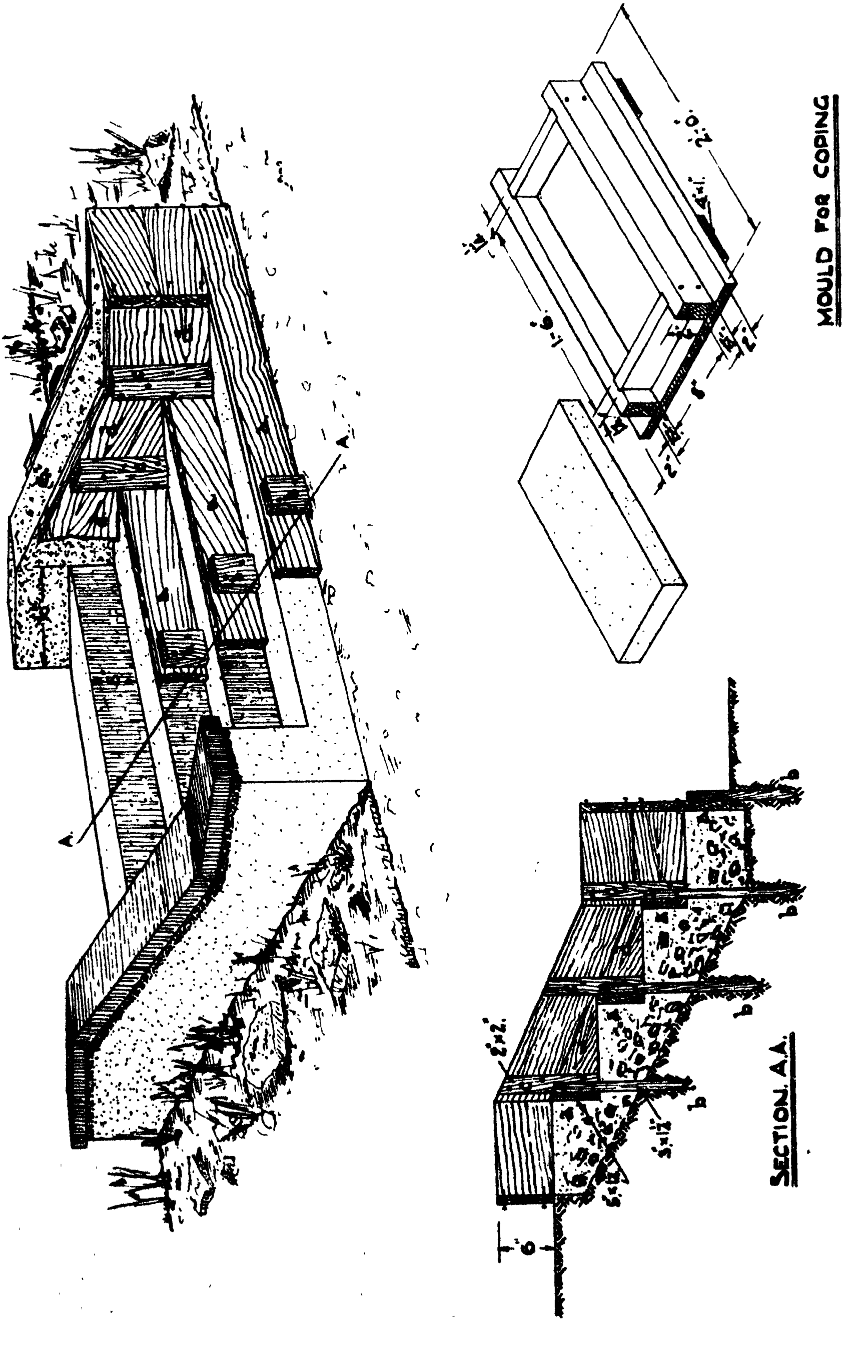


Fig. 4.—HOW TO ERECT GARDEN STEPS IN CONCRETE ON SITE

Showing method of fixing the shuttering for the steps and construction of mould for coping stones.

Dismantling the Mould

To dismantle the mould take off the clamps (*a*) shown on plan and then turn the mould and casting upside down, release the end and side forms, and leave the casting to harden before removing.

Curing the Casting

The casting should be kept fairly damp for seven days before allowing to dry out thoroughly.

Reinforcement

This casting should be reinforced with two $\frac{3}{8}$-in. diameter mild-steel rods hooked slightly at either end and placed central when filling the mould, spaced 2 in. from the top and bottom respectively.

Mix of Concrete

The mix of concrete should be 3 parts of $\frac{3}{8}$-in. to $\frac{1}{8}$-in. ballast, 2 parts clean sharp sand, and 1 part Portland cement.

Use of Steps

The gradients of the path are usually settled by the general slope of the site, though it is desirable to keep the inclination as easy as possible. If the path must of necessity be steep, a few steps at intervals are much better than a very steep slope. At the same time steps will look more attractive with flanking walls.

GARDEN STEPS

The general lay-out of gardens often necessitates the erection of steps in some form or another. The following deals with the job in detail, whether for the garden or any other position where steps are required.

As will be seen by Fig. 4, the work is proposed to be carried out with *in situ* concrete since it is cheaper and undoubtedly more durable than other materials suitable for this class of work.

The Design

Coloured cement can be used to keep the work more in keeping with the natural surroundings and pockets can be left in the strings to hold sufficient soil to enable flowers to be grown if desired. Such pockets can be formed by placing balls of clay immediately against the forms which can be raked out when the shuttering is dismantled.

The design is for steps 6 ft. between strings with 5-in. risers and 10-in. treads. The treads should have $\frac{1}{4}$-in. fall from back to front to ensure against water lying on the steps. The strings being 6 in. thick with pre-cast coping attached will enable pots or other garden ornaments to stand at the foot and head.

Excavation

The site should be more or less levelled lengthwise and well consolidated, as it so often happens that where such steps are required the ground has been made up, especially on new housing sites ; therefore consolidation is most essential.

Making and Fixing Shuttering

The shuttering for the strings should be made up and strengthened with 2 in. by 2 in. battens, as shown in section AA marked (*c*) ; screws should be used for fixing.

When fixing the shuttering, stumps marked (*b*) should be utilised on the outside of the strings and in the centre of the timbers which act as risers ; these should be securely fixed by screws and additional stumps could be temporarily fixed wherever required by nails.

It should be remembered to use a little grease on the screws when assembling, since the benefit of such will be reaped when dismantling.

Proportions of Mix

For this particular construction 4 parts of $\frac{1}{2}$-in. to $\frac{1}{8}$-in. graded ballast, 2 parts of clean washed sand, and 1 part of cement will give satisfactory results.

Coloured cements can be obtained if desired, and for garden work a buff-coloured cement should be ideal.

Placing the Concrete

When a batch of concrete is thoroughly mixed it should be placed between the shutters immediately and well tamped into position, leaving the top more or less rough to form a key for the following batch.

When placing the concrete which forms the steps, release the screws in the stumps marked (*b*) and withdraw them before the work is completed, fill in the cavity made by the withdrawals, and finish off the work.

Mould for Coping

The mould for the coping is quite a plain affair, being left square and 2 in. thick. The side forms can be either screwed or clamped together and fixed temporarily to the baseboard.

If made 8 in. wide, as shown, it will overhang the strings by 1 in. on either side.

A similar mix to that used for the steps can be utilised, taking care to well consolidate the concrete in the angles of the mould.

Fixing the Coping

When the castings are sufficiently hard they can be fixed to the strings of the steps by using sand and cement mixed 4 parts sand and 1 part cement.

Chapter VII

CONCRETE ROADS AND ROAD REPAIRS

IN no other work is concrete subjected to so many varying conditions as in road work. Extremes of heat and cold, moisture, impact, abrasion and vibration, tensile and compressive forces are continually in action; and it is essential, therefore, that only the very best British Portland cement should be used.

If it is desired to open the road to traffic as soon as possible after construction a rapid-hardening Portland cement should be used. The richer the mix the more rapid will be the hardening.

Proper storage should be provided, for it must be remembered that cement is by far the most important constituent of concrete since it supplies the binding strength. It deteriorates rapidly if exposed to the elements or if it is allowed to absorb moisture whilst awaiting use.

Coarse Aggregate

In practically every locality in Great Britain material is available which, either with or without treatment, is satisfactory for concrete road work.

The following are the materials which are generally used:

Gravel.—This should be clean and suitably graded, free from clay and other injurious matter. Only washed gravel should be used, obtained from pits which have an efficient washing plant, so as to ensure that it is free from coatings of any kind.

Whinstone, Basalt, Granite.—These are excellent materials and are particularly suitable for roads that have to carry steel-tyred traffic and to withstand severe abrasion.

One of the difficulties in connection with some types of granite is that the crushed material is apt to contain a fairly high percentage of stone which is either flat or flaky, probably due to the use of the wrong type of crusher jaw. Flat stones are apt to pick out of the surface and do not make so compact or dense a concrete as one in which the material is either round or cubical.

Limestone.—This is usually a suitable aggregate; but only those limestones having a high specific gravity should be used. Limestones of low specific gravity are definitely unsuitable for the wearing surfaces of concrete roads as they are liable to polish under traffic and produce slippery surfaces. Those of a higher specific gravity do not suffer from this disadvantage.

The softer-quality stone may be used in the bottom course of a two-course road, provided that any fine dust produced by the crusher is removed by washing or by other means.

Size and Grading.—The size of the aggregate is to a large extent governed by the thickness of the slab. Material suitably graded from 1½ in. down to $\frac{3}{16}$ in. is usually employed. The more important consideration is to select material that will give the densest possible concrete—a result which can be achieved only by careful adjustment, i.e. proportioning the material to be used.

It does not always follow that only uniform-graded aggregate makes suitable concrete. An aggregate which is suitably graded for one purpose may be very badly graded for another. Except for very rich mixes the grading that gives maximum density will not give workability, but carefully chosen proportions of medium and fine particles, without change of cement content, will produce a workable concrete with only a small decrease in density.

Very satisfactory roads have, for example, been laid in which the concrete has been proportioned as follows :

3 parts by volume of 2-in. broken stone.

1½ parts by volume of ¼-in. broken stone.

¾ parts by volume of sand.

1 part by volume of Portland cement.

For the top or wearing surface of a concrete road (referred to later under two-course work) it is advisable to use an aggregate of smaller size in order to obtain a smooth and closely knit running surface.

The material in this case is generally granite chippings or crushed ballast, graded from ¾ in. down to $\frac{3}{16}$ in., unless a rough surface is required, in which case 2-in. B.S.S. gauge material should be used.

The principle advantage to be obtained from reinforcement in concrete road slabs is that if any cracking takes place it enables any fractured portions to be held together. It is not used entirely to increase load-carrying capacity or to prevent cracking.

If plain steel bars are used it is advisable for the steel to be securely tied at the intersections so that it can be placed in the form of rigid mats. The various proprietary fabrics are supplied in this form ready for laying.

The Ministry of Transport do not recommend any reinforcement weighing less than 7 lb. per sq. yd. for rolled steel, or its equivalent in strength in drawn steel ; but this does not mean that by taking the minimum, one is necessarily acting for the best, and every case must be considered on its merits.

Thickness of Slab

The minimum thicknesses for concrete road slabs on all normal foundations are :

6 in. for private streets, housing estate roads, etc., up to 16 ft. in width.

7 in. for private streets, housing estate roads, etc., over 16 ft. and up to 20 ft.

8 in. for omnibus routes and roads carrying up to 5,000 tons a day.

9 in. for roads carrying from 5,000 to 10,000 tons a day.

10 to 12 in. for roads carrying over 10,000 tons a day.

A certain amount of disagreement still exists amongst engineers as to whether the road slab should be of uniform thickness or whether it should be thicker in the centre than at the sides.

When the results of the Bates Road Tests carried out in America in 1923 were analysed it was concluded that the edges should be thickened.

There are, however, many successful roads where the dimensions have been reversed, so that so far as is known there seems no reason to depart from a uniform section except in special circumstances, such as a wide road constructed in alternate bays. In this case it may be advisable to thicken the middle third of each bay to prevent longitudinal cracking due to any tendency of the slab to warp.

Continuous Construction

In this method the concrete is laid continuously, the only joints being those at the end of each day's work. There are no expansion joints. The system would appear to be applicable to districts with a constant humid atmosphere where the range of temperature is comparatively low.

The construction is simple for streets up to 16 ft. wide between kerbs as this is the limiting width beyond which hand tamping ceases to be efficient. Greater widths can be dealt with by pan-tamping the concrete to spot levels or to pads of concrete boned in from side forms.

Alternate Bay Work

The advantages of this method are that it can be used for any ordinary width of carriage-way and that the risk of transverse cracking is almost entirely eliminated owing to the construction being carried out in short bays. The slabs are usually constructed the full width of carriage-way and up to 15 ft. in length, all tamping being carried on in a longitudinal direction off forms shaped to the camber of the road and placed transversely.

Where the width of the carriage exceeds 16 ft. there will be a risk of longitudinal cracking, which can, however, be eliminated by forming a dummy joint along the centre of the road.

The chief disadvantages of this method are those in connection with cost, and with the danger of settlement of the alternate or intermediate bays, should these be concreted on a foundation affected by a prolonged spell of wet weather, frost, etc.

To meet these contingencies it is advisable to introduce an efficient mechanical connection between each bay, such as dowel bars, or alternatively to provide a good interlocking joint.

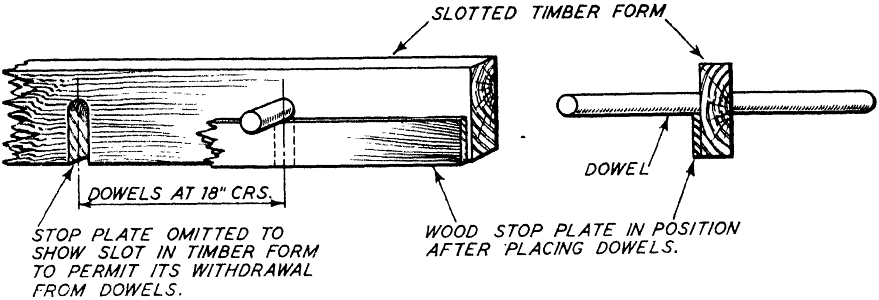


Fig. 1.—METHOD OF SUPPORTING DOWEL BARS

Expansion-joint Method

This is similar to the continuous-construction method, except that expansion joints are provided at predetermined intervals. This construction is suitable for strips up to 16 ft. wide. A greater width than this is not recommended owing to the tendency for longitudinal cracks to develop along the middle of the road as a result of slab movement.

In the early days of concrete roads 60 ft. between expansion joints was a common interval, but the tendency to-day is to halve this distance.

Strip Method—Continuous Construction

This method of construction is the only practicable and economical method of concreting the carriage-way in such widths as will allow traffic to use that portion which is not immediately required for constructional purposes. Carriage-ways from 18 ft. to 30 ft. between kerbs are generally laid in half-width strips. Carriage-ways from 30 ft. to 45 ft. in width would be constructed in either three or four strips according to requirements.

As a general rule the strips are made about 30 ft. long, expansion joints being formed at the end of each, and the concrete work being progressive from bay to bay.

Where dowel bars are provided at expansion joints the strips must be laid alternately, the intermediate bays being filled in later unless special provision is made for supporting the dowel bar in position during the placing of the concrete. This support can be provided by means of small wire cradles which are left in the concrete.

If the bays are concreted alternately the dowel bars can be supported by means of a wood stop plate as illustrated in Fig. 1.

One-course Work

A properly proportioned concrete well mixed and placed, and in which a good sand and a hard-wearing stone are used, will be found suitable for practically all types of modern traffic without the necessity of providing special aggregates or richer mixes for the top course or wearing surface.

Two-course Work

This is usually adopted for one of the following reasons :

(*a*) For roads that have to carry a considerable amount of steel-tyred traffic.

(*b*) When the available aggregate is not sufficiently tough or has a high percentage of flat particles. Limestone may make an excellent concrete but is liable to polish in course of time. For this reason it is advisable to use this material in the lower course and complete the slab with a tougher material such as granite chippings, crushed stone, etc.

(*c*) When it is desired to add a coloured surface to the road, in which case the top 1½ in. to 2 in. only need be coloured.

(*d*) When it is desired to provide a roughened surface to afford extra grip for traffic on gradients—see " Roughened-surface Construction."

In view of the small amount of wear that takes place on a well-constructed road the depth of the top course may be from 1½ in. to 2 in. It is seldom, if ever, necessary to decrease this dimension.

Roughened-surface Construction

This is another form of two-course construction of particular value for gradient work. Whereas concrete, finished as previously described, is quite suitable for all ordinary gradients, it is considered advisable to provide a roughened surface for any slope steeper than 1 in 18.

This effect can be produced in a variety of ways, the most general and probably the most satisfactory being the introduction of large granite or similar cubical material—2-in. B.S.S. gauge—into the top course of the concrete slab in place of the finer stone that would usually be specified.

The bottom-course concrete is laid and tamped to the required level in the ordinary manner, followed at an interval of not more than half an hour by the large granite aggregate topping.

The mix for the latter is usually in the nature of 1 part cement, 2 parts sand, and 5 parts stone, as it has been found that a lesser ratio of stone to sand is likely to create an excess of mortar when tamping takes place and may thus give too smooth a finish unless such surplus is removed by brushing.

In any case a small amount of brushing with a hard broom is desirable in order to expose the coarse aggregate, so that it stands slightly " proud " of the surface. This process should be carried out when the concrete is sufficiently hard to prevent displacement of the top-course aggregate, but not hard enough to prevent the removal of the mortar round the individual stones.

The resulting surface approximates closely in both texture and appearance to that of waterbound macadam, and the excellent grip thereby afforded to horses and vehicles cannot be too strongly emphasised.

The expansion joints for this type of road are made in the usual manner except that it is not generally necessary to round the arrises.

The presence of large stone in the surface eliminates the risk of ravelling of the edges at the joints.

Foundation

Either a uniformly soft or uniformly hard foundation is satisfactory, but one that is soft in one place and hard in others will never give a reliable bearing value unless properly treated.

Boulders or rock outcrops that are within 6 in. of the bottom of the slab are objectionable and should be removed. Earth, gravel, or macadam that has been thoroughly compacted and which may be within 1 ft. of the bottom of the slab should be examined, and if necessary scarified and recompacted to ensure uniformity.

Special precautions must be taken where the slab is wider than the old surface to ensure equal support for centre and edges. All spongy or soft places must be removed and made good with suitable material.

A road roller is of value to smooth out high places, discover soft places, and consolidate filling and embankments as the work proceeds. A 10-ton roller is superior for heavy filling such as embankments, etc., but for compaction and all ordinary grading work one weighing 5 tons is preferable.

Poorly consolidated trenches are bad foundations. Road construction is frequently preceded by the installation of water, sewer, and gas service pipes. When these newly made trenches are back filled they should be thoroughly tamped, and if possible saturated with water to ensure complete settlement.

Checking Foundation Level

It is customary to require that the foundation be within ¼ in. of its correct level before concreting takes place. This level may be ensured by means of a scratch template or template with headless nails driven into its lower edge so that their sharpened ends are at the correct elevation when the template rests on the side forms.

Surface Treatment of Foundation

Except where laid on sand and gravel it is now the almost universally accepted practice to provide an insulating medium between the underside of the concrete slab and the foundation. This may consist of either sandy gravel, well-burnt clinker, or other suitable material, and should be consolidated by mechanical means until a final thickness of 2 in. to 3 in. is obtained for normal sites. This gives the slab freedom of movement during expansion and contraction, prevents any dirt being worked into the concrete as it is being deposited, and acts as a cushion against any pressure of the sub-base due to expansion in warm or wet weather. It is now becoming the general practice to spread specially prepared water-

proofed paper on this insulating layer before placing the concrete. This prevents absorption of any liquid cement into the sub-base and, where laid on clinker, tends to prevent any deleterious action which might occur through impurities in the clinker being absorbed by the underside of the slab.

Placing Reinforcement

Great care must be exercised in placing the reinforcement. One of the most common faults in the construction of concrete roads or foundations is to allow the reinforcement to lie on the sub-base or too near to the sub-base to permit the steel being properly protected with concrete ; it must never be nearer than 1½ in. to any surface.

The placing of reinforcement when ordinary mild-steel bars are employed does not call for any particular description, inasmuch as the method is in every respect similar to that used in reinforced-concrete floor construction.

Road reinforcement in the form of a proprietary mesh is usually delivered in flat sheets or in rolls. Accurate placing is very much facilitated if sheets are employed. The usual method adopted is first to spread a layer of concrete equal in depth to the specified distance of the reinforcement from the bottom of the slab. This layer of concrete is gently tamped either with a hand rammer or a tamper worked between the forms and notched to give the correct depth of concrete. (It is advisable to make this layer slightly wetter than the remainder of the slab.) The reinforcing sheets are placed on this layer of concrete and then the concrete deposited for the remaining depth of the slab. It is necessary to restrict the length of concrete spread in this manner at any one time, depending a good deal on the speed of concreting ; but generally speaking, it should not exceed 15 ft.

Placing Concrete

The necessity of placing the concrete within thirty to forty minutes of the time that the water has been added is sufficiently well known to need no emphasis.

Forty minutes is taken as a standard for nearly all cements as this is known to be a reasonable and safe period. It is true that this may be extended in cool or cold weather, but on well-organised work the concrete is generally placed well within this limit.

With closed drum mixer the contents of the drum should be discharged in one operation, otherwise successive batches will not be of uniform character.

Concrete conveyed from the mixer in skips or hand trucks should, at the end of the haul, be deposited on a stage or platform and thence shovelled into its final position. This is a necessary procedure in the case of long hauls in order to avoid segregation.

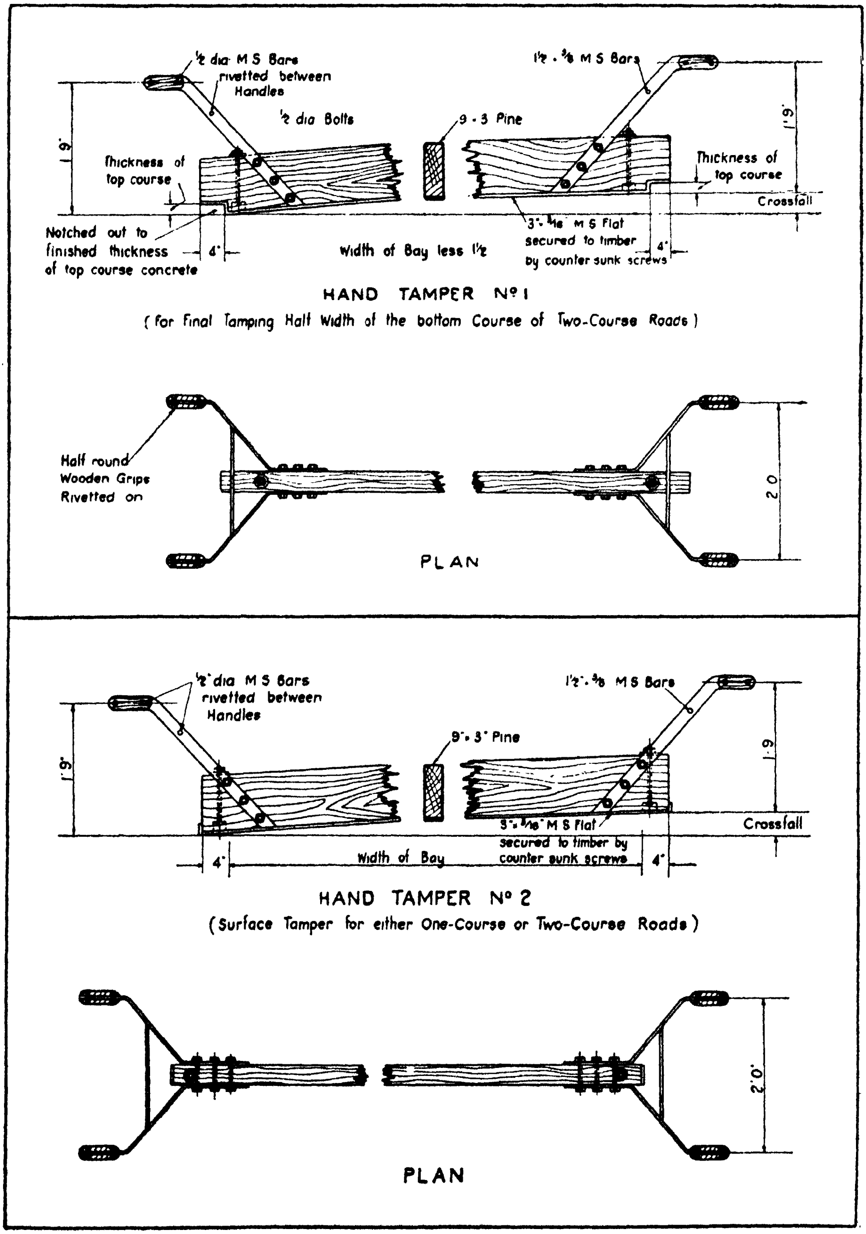


Fig. 2.—HAND TAMPING TOOLS
(*The Cement and Concrete Association*)

Various types of plant are used in depositing concrete, ranging from the ordinary wheelbarrow to the large mechanical distributor.

For ordinary road work a satisfactory and economical method of depositing concrete consists of a light metal boom spanning the road under construction, the concrete being discharged from the mixer into a small side-tipping skip which travels along the boom and can thus deposit the concrete at the face of the work.

For work in congested areas, town roads, etc., where space is limited and mixing has to be carried out in a position some distance away from the site, the method by which the concrete is loaded into side-tipping lorries which draw up at the side of the work, where they discharge their contents quickly, causes the minimum amount of traffic delay.

For main or arterial road work of any magnitude a mechanically operated distributor is desirable for the reason that it combines the operations of discharging and spreading, and eliminates all hand work.

It is advisable to use a "fat" concrete, or one slightly deficient in coarse material, next to joints when work ceases at any time so that there may be no risk of honeycombing at these positions. The first batch mixed in the morning also requires watching, for some of its mortar is likely to cling to the mixer blades and drum, thus giving a harsh concrete which should be carefully avoided.

Whenever work ceases for a sufficiently long period to allow the concrete to commence hardening, a vertical butt joint should always be made and the concrete prevented from forming an irregular and sloping line. Such a line will create a weakness which would cause trouble under the thrust of expansion or cracking as the slab contracts.

When the mixer is stopped for only ten or fifteen minutes the new and old concrete should be thoroughly "sliced" together with shovels to ensure that no cleavage plane is formed.

Tamping Concrete

The importance of thoroughly consolidating the concrete cannot be too strongly emphasised, for it is this process that ensures a dense homogeneous mass free from voids, honeycombing, and surface irregularities.

If the road is laid in two courses both are usually tamped, and the tools recommended for this are illustrated in Figs. 2 and 3.

Tampers should be cut from selected timber so that the weight per foot run is as constant as possible throughout their length. Alternatively they may be purchased from a firm experienced in the manufacture of these tools.

All concrete placed against the form faces, or against completed work, should be "sliced" in order to ensure that a close-knit surface free from voids or cavities is obtained. The best tool for this purpose is a short piece of bar iron with one end flattened to a width of 3 to 4 in.

A straightened hoe or narrow spade with holes punched in it is also

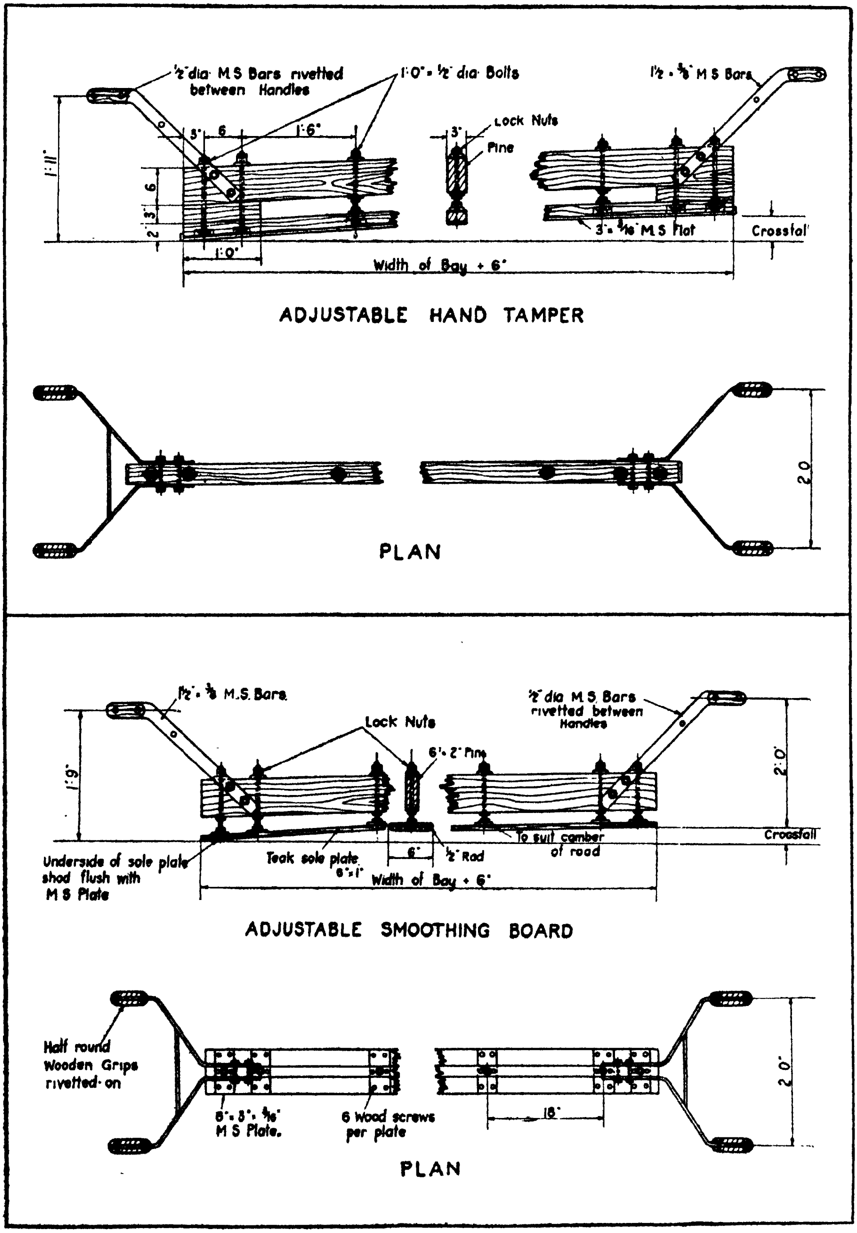


Fig. 3.—ADJUSTABLE HAND TAMPER AND ADJUSTABLE SMOOTHING BOARD
(*The Cement and Concrete Association*)

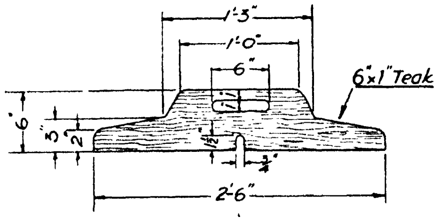


Fig. 4.—STRAIGHT-EDGE FOR TRUING UP TRANSVERSE JOINT

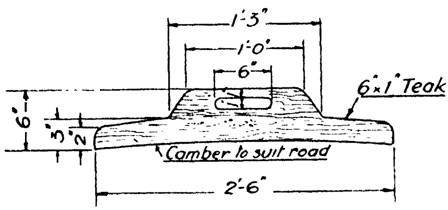


Fig. 4A.—TEMPLATE FOR TRUING UP LONGITUDINAL CENTRE JOINT

(*The Cement and Concrete Association*)

useful for such work, for as the tool is worked up and down against the form face mortar is drawn to the edge of the slab, ensuring that the face is free from honeycombing.

Types of Joints

There are two general types of joints. One that provides for expansion of the concrete, referred to as an expansion joint, and the other constructed to forestall irregular cracking and known as contraction joint.

Any type of expansion joint belongs to the first group, though it also prevents natural cracks. Longitudinal and " dummy " transverse joints belong to the second group.

Construction joints may belong to either, and are put in wherever the construction requires them.

Transverse Joints

For many years transverse joints consisted of little more than spaces left in the slab at more or less haphazard intervals and filled with some premoulded bituminous material. Experience has shown, however, the necessity of designing these joints with care.

Width of Joints and Distance Apart

The allowance generally made for the width of joints is at the rate of about ¾ in. per 100 ft.

Experience has shown that in those parts of the British Isles where the temperature changes are not high—North-West England, South Wales, and Ireland, joints may be safely placed at intervals of 50 ft. to 60 ft. or even more. In London and district and the South Coast, the most satisfactory spacing seems to be in the order of 30 ft. to 35 ft.

For main roads where high-speed traffic may be expected, it is recommended that the placing of expansion joints should be unequal, since uniform spacing may result in periodic oscillation being transferred to the vehicle. For roads in this country the spacings recommended are 30 ft., 33 ft., 37 ft., and 40 ft.

Construction of Joints

Two of the chief essentials in joint construction are that the joint shall be truly perpendicular to the surface of the slab and that all arrises are rounded.

A radius of ½ in. has proved very satisfactory, provided the rounding is done in such a manner as will preserve the level relative to the adjoining surface. This can be accomplished without difficulty by the use of a small edging tool in conjunction with a 2 ft. 6 in. straight-edge to check the surface level across the arrises so rounded. It is essential that this work be done when the concrete has set sufficiently to keep the shape given it by this edging tool.

Transverse joints should be at right angles to the kerb and continue straight across the carriage-way, the joint filler, in the case of expansion joints, being continued from one edge of the slab to the other. If diagonal joints are required these should be at an angle of 80° or more to the kerb if the strip method of construction is adopted.

When a premoulded filler is used it should be held upright by either a timber or metal form securely held in its correct position on the sub-base.

Metal forms are better than timber for this purpose because they are thinner and leave only a small space along the filler on their removal, thus making it easier to obtain a perpendicular joint.

A metal form which is very popular in some countries consists of one which is folded over to form an envelope for the top of the filler and so hold it down and prevent any tendency of the concrete to float it out of position.

If the bottom half of this form or stunt-head is notched like a saw with fairly deep and wide notches the concrete as it is thrown against it will come in contact with the filler through these notches, and so hold it in position when the stunt head is removed (see Fig. 5).

There are on the market premoulded fillers that do not extrude when compressed in hot weather, and that regain their shape after such compression, also there are copper strips designed to seal the joint permanently.

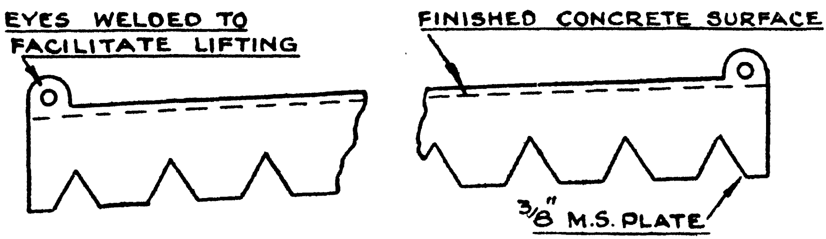


Fig. 5.—CROSS FORM SERRATED TO FACILITATE WITHDRAWAL

Poured Joints

"Poured joints" are sometimes adopted and are formed by means of a tapered metal form which is built in when the slab is moulded. After the concrete has hardened sufficiently the form is carefully removed and the space it occupied filled with a bitumastic filler.

Although these joints are easier to construct than the other types mentioned, there is always the danger of the concrete near the joint being broken away when the metal form is removed, particularly when there is any difficulty, as is usually the case, in breaking down the adhesion of the concrete with the form face, even though the latter is tapered and thoroughly oiled to prevent such action.

Dummy Joints

Dummy joints are frequently introduced to ensure that in the event of cracking taking place such cracks will occur along predetermined planes. The dummy joint generally consists of a groove 2 or 3 in. deep formed in the top of the slab before the latter has hardened by means of a double-edged arrising tool, or by using a sharp-edged wheel which is run along a straight-edge laid on the finished surface.

Dummy joints are effective, look well, and cost practically nothing to make. The joint groove, which should be $\frac{1}{8}$ in. to $\frac{1}{4}$ in. wide with edges rounded and finished in a similar manner to other joints, should be filled with a good bituminous material before the road is opened to traffic.

Stone Sett Joints

Where there is a large proportion of steel-tyred traffic a joint consisting of either concrete or granite cubes with 4-in. or 5-in. sides can be adopted.

If the concrete has a depth of 8 in. or more the setts can be laid in a recess left for them, attaching a piece of timber 3 in. or 4 in. square to the cross forms.

Owing to the reduction in the thickness of the concrete to form a recess for the setts, it will be necessary to have a concrete bearer about 2 ft. wide and 4 in. thick under the joint. The surface of this bearer should be covered with paper or tar to prevent adhesion.

Dowel Joints

Dowel bars are used across transverse and longitudinal joints to prevent vertical movement of the slabs, and to transmit loads from one slab to its neighbour.

On bad ground such as peat or ground in mining areas where subsidence is likely to occur, dowel bars have proved of great assistance.

Dowel bars are mainly used at transverse joints. In this case they are bounded into one slab, but have the bond broken in the other by being coated with tar or wrapped with paper. They have also proved of value

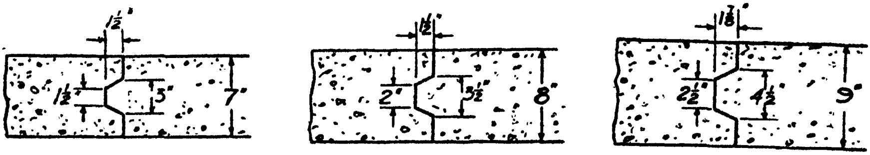


Fig. 6.—LONGITUDINAL "T AND G" JOINTS
(*The Cement and Concrete Association*)

for the longitudinal joint of road slabs on embankments, etc., where they counteract any tendency for the slabs to move outward and the joint to open.

At expansion joints it is necessary to provide a small space at the free end of each bar into which they can slide, otherwise the bar will bend under the thrust of the expanding slab and probably shatter the concrete. If the bond is not broken a crack will form in the concrete at the end of the bars as the slab contracts.

The space for expansion may be formed by placing on the free end of the bar a metal or cardboard sleeve slightly larger than the bar in diameter. One end of this is filled with compressible material such as cotton waste or something similar into which the bar can push. It should be at least as deep as the width of the expansion joint.

Dowels must be smooth and are usually ¾-in. round mild-steel bars about 3 ft. long placed half-way down the depth of the slab and spaced at not greater intervals than 18 in.

Interlocking Joints

These have been successfully used on main-road construction. They are reasonably cheap and easy to construct, the principal requirement being a well-tamped and thoroughly dense concrete wherever they occur.

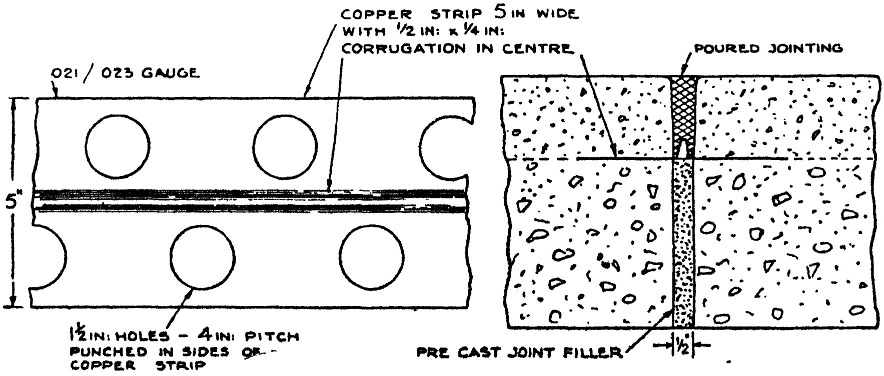


Fig. 7.—SECTIONAL VIEW OF COPPER STRIP JOINT
(*The Cement and Concrete Association*)

Tongue and Groove Joints

The longitudinal joints in concrete roads are frequently specified to be of the tongue and groove type, the main object being to prevent vertical movement of the slabs. Such joints are generally made to the dimensions shown in Fig. 6.

Watertight Joints

Damage is sometimes caused to concrete slabs due to water finding its way through the joints on to the foundation, which may become so wet that it ceases to support the slab.

An efficient and simple watertight joint can be formed by the introduction of a corrugated copper strip, as shown in Fig. 7.

This is laid horizontally across the joint and about 2 in. from the slab surface with a vertical strip of soft wood or fibre board below and some form of pliable filler above.

This type of joint eliminates the extrusion of the ordinary joint filler in hot weather, and when the joint has to be renewed it is only necessary to refill the 2-in. space above the strip.

Even when the slabs are at their maximum distance apart in cold weather and the filler leaves one face of the concrete, water cannot penetrate to the formation.

CONCRETE ROAD REPAIRS

Maintenance

The maintenance of concrete roads is almost invariably limited to the attention to joints. Worn-out portions of the joint filler should be removed and each joint made thoroughly watertight by means of a suitable bitumastic or other plastic material, either poured or caulked into the joint.

Should cracks occur they should be attended to as early as possible by giving each crack one or two coats of special sealing material or emulsified bitumen, which is better for sealing purposes than plain bitumen.

Attention to cracks and joints should be carried out in the autumn when they are open so that they may be sealed against the entrance of moisture during the winter months.

There is now available for sealing joints and cracks a material of practically the same colour as concrete, which can also be obtained in various colours to match coloured concrete work.

Repairing Fractures

No temporary expedient can be recommended. The fractured portion must be removed and made good with new concrete, mixed with as little water as possible to avoid shrinkage. The old formation must also be examined and if necessary made good with new material.

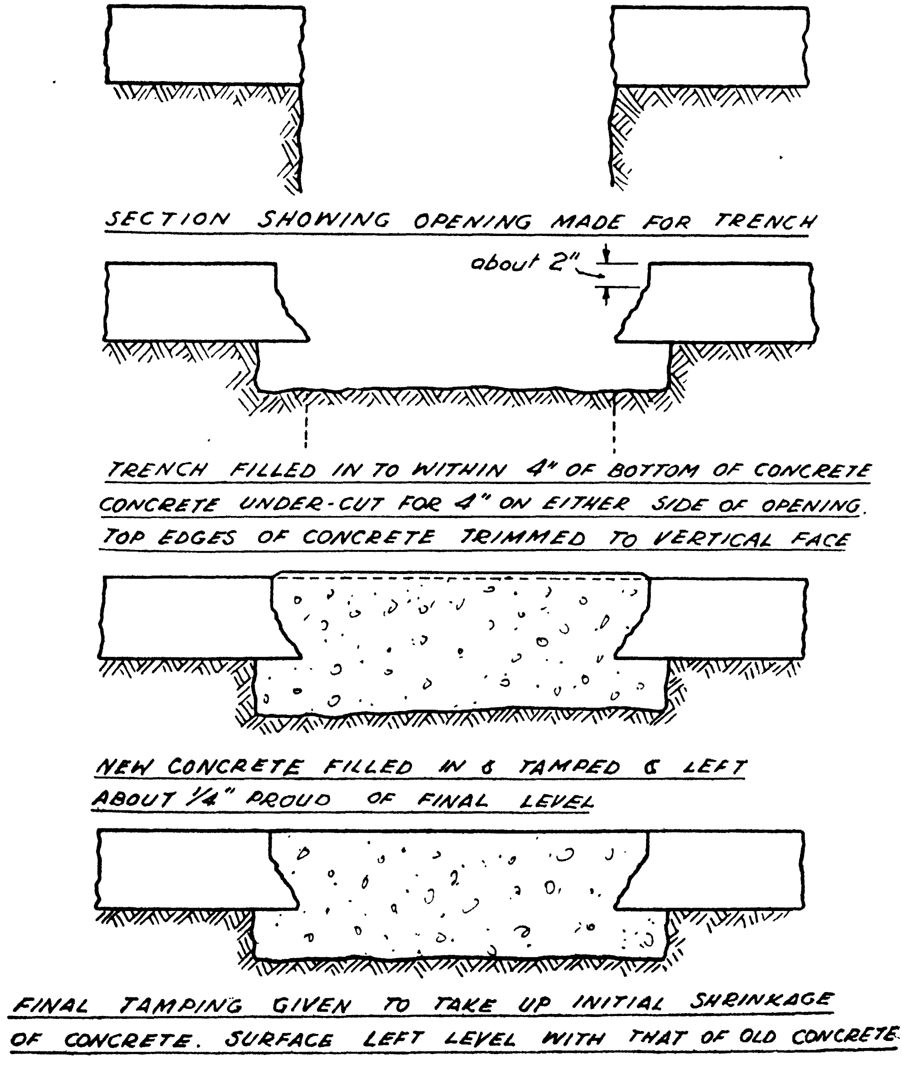


Fig. 8.—METHOD OF REPAIRING FRACTURED CONCRETE ROAD

It is a good practice to extend the new concrete about 4 in. below and 4 in. under the edges of the old slab to help support those edges (see Fig. 8).

The edge of the original slab should be cut back to an angle of roughly 45°, except the top 2 in., which should be as vertical as possible.

The faces of the old concrete should be thoroughly cleaned and wetted, and given a coat of neat cement grout before the adjacent new concrete is

deposited. The fresh concrete should be retamped an hour or so after being placed to take up any initial shrinkage and to ensure a close-knit finish.

Removable Wearing Surfaces

As already stated, experience has shown that the wear of concrete road surfaces is negligible over a considerable period of time under ordinary traffic conditions.

In special circumstances, such as excessive trucking, the abrasive effect of grit may wear away the toughest granite whether it be in the form of concrete aggregate or stone setts, etc., and necessitate the reinstatement of the worn portions.

In such cases the use of concrete provides an economical, speedy, and effective means of surface replacement if used in conjunction with cleavage fabric placed between the bottom- and top-course concrete, or about 3 in. from the surface if single-course work is being carried out.

The cleavage fabric may be of jute or scrim of about $\frac{1}{8}$-in. mesh, and should be damped before being placed in position so that it will not absorb moisture from the concrete when this is spread over it. The placing, tamping, and finishing of the top-course concrete is carried out in the usual way.

Though the presence of the cleavage fabric breaks the key between the courses it does not in any way interfere with the normal behaviour of the slab, yet it enables the top course to be readily stripped when required.

Before placing this new top course the surface of the existing concrete should be freed from all loose material and lightly damped, care being taken to see that no free water is allowed to remain on it.

The new wearing-course concrete is then placed, tamped, and finished in the usual way. Experiments carried out in England show that this method is entirely successful.

Concreting in Cold Weather

An increasing interest is being taken by engineers and contractors in the possibilities of laying concrete roads in frosty weather. It is found that by raising the temperature of the concrete to between 55° and 65° F. the chemical action involved in the setting and hardening of the concrete is started. If, after placing the concrete, adequate protection is given, the heat is retained and the chemical action continues.

The method most commonly adopted of raising the temperature of the concrete is to heat the mixing water, and the means adopted on various jobs are described below.

A method adopted at Brighton for heating the water was to use a boiler of the domestic type rated to give $1\frac{1}{2}$ gallons of hot water per minute at 180° F. The mixer was a 10/7 cu. ft. machine. An important feature of the system was the location of the closed 60-gallon tank on top of the

mixer outside the ordinary water tank, which should preferably be lagged. The total cost of this plant additional to the cost of the mixer was £23.

At Bray, Ireland, the water was heated in old petrol drums and was placed in the mixer at a temperature of about 180° F. The temperature of the concrete when spread was 65° F. to 70° F.

On a works road at Beddington, Surrey, the water for the 7/5 cu. ft. mixer was heated from an air temperature of 20° F. by a steam jet from the boiler of a steam wagon, the jet passing into a 150-gallon open tank. The latter was filled by using the lifter pipe of the wagon. Concrete from the mixer had a temperature of 60° F. and when placed it had a temperature of 50° F. An output of 130 sq. yd. of concrete a day was reached without difficulty and the road was open to traffic within seven days of completion.

Hand Finishing

This is the most common practice in this country and is carried out by means of tampers or smoothing boards shaped to the camber of the road.

Three types of finish can be given to a concrete road.

(1) The normal type as produced by a smoothing board.

(2) The tamped finish which gives a ridged or corrugated finish.

(3) The rough surface or exposed aggregate finish which leaves the coarser particles of the mix standing proud of the surrounding mortar.

The smoothing board enables a true surface to be quickly obtained as compared with surfaces finished with tampers only. Only a limited use of the smoothing board must be made, i.e. two traversings of the surface with it should suffice if the mix and consistency of the concrete are correct. The tool should be used with a to-and-fro motion across the concrete, a slow advance longitudinally being given to it at the same time. Excessive use of this tool, or any use of it as a tamper, will be detrimental, as this will bring an excess of fine material and laitance to the surface.

In many parts of this country the tamped finish is the most popular, the necessary smoothness of the surface being obtained from the tamper without recourse to a smoothing board.

It is obvious that care must be taken in the second method to ensure that waves are eliminated as much as possible. The preference for this method is in some measure due to the idea that the use of the smoothing board decreases output by causing delay in finishing, but this is proved to be a fallacy in practice.

Too much tamping on any process that brings an excessive amount of mortar to the surface is undesirable as this causes scaling and dusting and provides a surface that will not resist hard wear.

Curing

Curing is the treatment or protection given to concrete during its hardening period. Proper curing means keeping the concrete moist enough and warm enough to ensure adequate hydration of the cement.

Quantities of Materials Required per Square Yard of Road Surface

(Based on loose cement weighing 90 lb. per cu. ft., damp sand (30 per cent. bulked) 84 lb. per cu. ft., broken stone 90 lb. per cu. ft., and shingle 109 lb. per cu. ft.).

TABLE I

USING BROKEN STONE AS COARSE AGGREGATE

Thickness of Slab or Course	1 : 2½ : 4 *mix*			1 : 2 : 3 *mix*		
	Cement	*Sand (damp)*	*Coarse Aggregate*	*Cement*	*Sand (damp)*	*Coarse Aggregate*
in.	*lb.*	*cu. ft.*	*cu. ft.*	*lb.*	*cu. ft.*	*cu. ft.*
1	14·5	0·42	0·64	18·1	0·39	0·60
1½	21·8	0·63	0·97	27·2	0·58	0·90
2	29·1	0·84	1·29	36·3	0·78	1·20
3	43·6	1·26	1·93	54·4	1·17	1·80
4	58·2	1·68	2·58	72·6	1·56	2·40
6	87·3	2·52	3·87	108·9	2·34	3·60
7	101·8	2·94	4·51	127·0	2·73	4·20
8	116·4	3·36	5·16	155·1	3·12	4·80
9	131·0	3·78	5·80	163·2	3·51	5·40
10	145·5	4·20	6·45	181·4	3·90	6·00
12	174·7	5·04	7·74	217·7	4·68	7·20

TABLE II

USING SHINGLE AS COARSE AGGREGATE PER SQUARE YARD OF SURFACE

Thickness of Slab or Coarse	1 : 2½ : 4 *mix*			1 : 2 : 3 *mix*		
	Cement	*Sand (damp)*	*Coarse Aggregate*	*Cement*	*Sand (damp)*	*Coarse Aggregate*
in.	*lb.*	*cu. ft.*	*cu. ft.*	*lb.*	*cu. ft.*	*cu. ft.*
1	13·4	0·38	0·59	16·6	0·36	0·55
1½	20·0	0·57	0·89	24·8	0·54	0·83
2	26·7	0·76	1·18	33·2	0·72	1·11
3	40·1	1·15	1·78	49·7	1·08	1·66
4	53·4	1·53	2·37	66·2	1·44	2·22
6	80·2	2·29	3·55	99·4	2·16	3·33
7	93·5	2·67	4·14	115·9	2·52	3·88
8	106·8	3·06	4·73	132·5	2·88	4·44
9	120·2	3·44	5·32	149·0	3·24	4·99
10	133·6	3·82	5·92	165·6	3·60	5·54
12	160·3	4·58	7·10	198·7	4·32	6·66

NOTE.—Normal mixes such as 1 : 2 : 4, 1 : 1½ : 3, etc., are based on all materials being in a bone-dry condition. Sand as used under ordinary conditions is always damp and bulks about 30 per cent, so that a 1 : 1½ : 3 mix should actually be specified as 1 : 2 : 3, in which allowance is made for this bulking. The above tables are based on damp sand 30 per cent. bulked.

Chapter VIII

SURFACE TREATMENT OF CONCRETE WALLS AND FLOORS

WALLS

Building with Different Mixes

THE methods of finishing concrete walls by building with different mixtures of concrete depend largely for their effect upon the colour of the concrete and the aggregate, and to make the wall of these special materials for its full thickness would be expensive. Concrete walls can now be built in two different materials at the same time in the following manner. The two different mixes are separated by means of a steel shutter, from 4 to 6 ft. long, about 2 ft. deep and $\frac{1}{8}$ in. thick, which is placed from $1\frac{1}{2}$ in. to 2 in. away from the outer shuttering. The facing mixture is first put into the narrow compartment, and the

Fig. 1.—DORCHESTER HOTEL, PARK LANE, LONDON

The front is entirely faced with precast concrete slabs built in as the main walls were cast in the shuttering. The facing slabs are composed of No. 2 Snowcrete mixed with crushed Botticino marble.

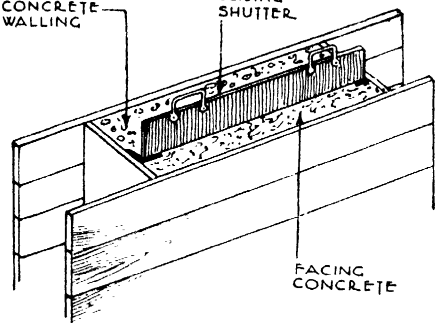


Fig. 2.—BUILDING WITH DIFFERENT MIXES OF CONCRETE

The two different mixes are separated by means of a steel shutter.

ordinary concrete filled in behind (Fig. 2). The two tips of concrete are then thoroughly consolidated and the steel shutter drawn out, thus allowing them to bond together. A simpler method is to divide the two mixes by means of expanded metal or wire mesh, which remains permanently in the structure, the two concretes amalgamating through the meshes.

Precast Concrete Slabs

Concrete facing is also done by means of precast slabs, which are cast in moulds and generally have a grooved sinking all round the edge, with reinforcing bars left projecting at the back to assist in bonding.

The slabs can be cast in a variety of colours by using special aggregates, and either white or natural Portland cements. The Dorchester Hotel in Park Lane, London, is an example of this method of building (Figs. 1 and 3). Here the slabs were made up with a mixture of Botticino marble chippings and cream-coloured cement.

The method of construction was to use the precast slabs as the outer face of the shuttering, a 2-in.-thick layer of cork was employed for the inner, and the reinforced-concrete wall was joined in between them. The Dorchester Hotel slabs were about 2 ft. long, 1 ft. high, and 2 in. thick, and the face was polished to a surface similar to a fine terrazzo floor.

Finished Surfaces Formed by Shuttering

A number of different finishes can be given to concrete walls by arranging the timber of the shuttering so as to give different impressions on the mixture when set. Nearly all types of planking will leave a mark on the face of a poured reinforced-concrete wall when removed, although in close-grained hardwoods the impression of the grain is almost invisible.

Grooved and Tongued Boards

The use of narrow grooved and tongued boards in the sides of the shuttering will leave a definite impression of lines on the face of the concrete wall ; by using boards over 6 in. in width these lines can be emphasised into ridges, as the wider planks will curve when in contact with the wet concrete mass. This is a very effective finish for the lower storeys of a building, where the large boards, marking strong horizontal lines, give scale. To obtain even more pronounced horizontal lines on

the concrete, square-edged boards should be used in place of tongued and grooved (Fig. 4).

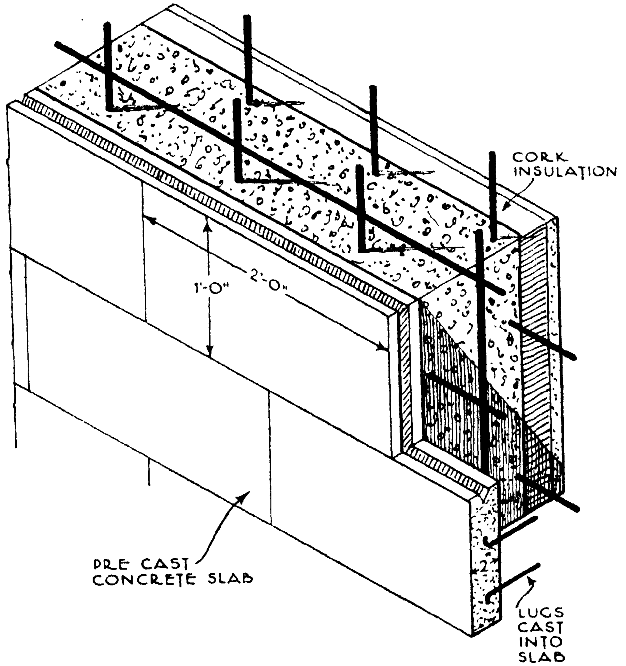


Fig. 3.—FACINGS OF PRECAST CONCRETE SLAB AT THE DORCHESTER HOTEL

Oiled Planks

The grain of the planks can be prevented from rising and marking the concrete by coating the inside of the prepared formwork with oil, and a much more uniform surface can be obtained by using oiled instead of unoiled planking.

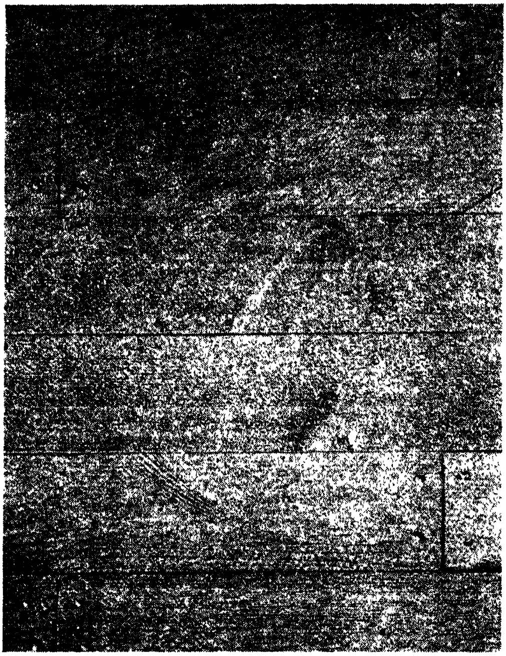
If the shuttering is composed of chamfered boards, a V-shaped projection is formed between each on the face of the concrete. Boards bevelled $\frac{1}{16}$ in. deep and $\frac{1}{4}$ in. wide will give a projection $\frac{1}{2}$ in. in width, which is very effective when employed with 4-in. or wider planking. By increasing the width of the chamfer a very pronounced moulding will result, which from a distance will have the appearance of a rustication (Fig. 5).

Weather-board Shuttering

Sometimes the outer face of the shuttering is laid with overlapping weather-boards, but as the result is only to give the concrete surface the appearance of a petrified wooden wall when the shuttering is removed, there is little to recommend this practice.

Plywood and Canvas

Plywood and canvas are sometimes used to give special finishes. The former produces a dead-smooth face broken into large panels by the slight projection of the concrete at the joints. The latter reproduces the grain of the canvas and masks all joints.



By courtesy of the Cement & Concrete Assn.

Fig. 4.—FACE OF CONCRETE AFTER THE REMOVAL OF SHUTTERING MADE OF 4-IN. SQUARE-EDGED BOARDS PLANED ON ALL SIDES

Crêpe Rubber

Crêpe rubber has also been used for lining the inside of the shuttering. It is a material that can be used over and over again, and will give a broken surface to the concrete wall either as a texture to be left exposed, or as a key for holding plaster.

Exposed Aggregate

Another finish is to expose the aggregate with which the wall is compounded by removing the skin of cement which forms against the shuttering. This may be done in several ways.

Retarders

One of these methods is to paint the shuttering which comes in contact with the concrete surface with a special cement retarder. These can be bought either in liquid form or in jellies, and their property is to act upon the surface skin and prevent it from setting, so that when the shuttering is removed at the end of about a fortnight this unset cement can be brushed off, leaving the aggregate exposed.

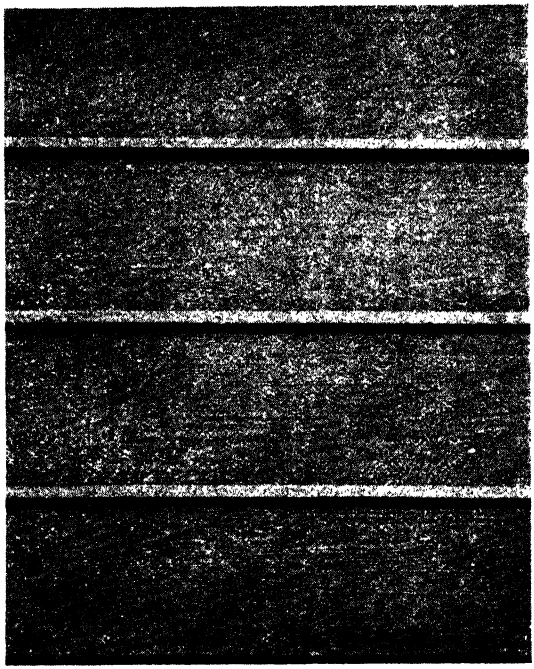
Bush Hammering

Another method, which may be carried out either by machine or by hand, is known as bush hammering. This is a process somewhat similar to scrubbing, as it cuts away the hard mortar and leaves the aggregate, but care must be taken in its use, for unless the wall has thoroughly set the small particles of aggregate will be knocked away with the cement. For this reason it is dangerous to bush hammer near angles or sharp mitres, and where these occur the work should be hand tooled, as the edges may spall.

Sand Blasting

Sand blasting can also be employed on a concrete wall to expose the aggregate. The usual method is to force a stream of sand through a

compressed-air machine, and by means of a nozzle direct it against the concrete surface, when the skin will come away with the sand. Workmen employed in this process should be properly protected by means of respirators from inhaling the minute silicon particles, and on the whole the method is one better employed in the workshop on precast work, than on the wall of a building in course of construction.



By courtesy of the Cement & Concrete Assn.

Fig. 5.—ROUGH-SAWN TIMBER IN SHUTTERING BEVELLED TO GIVE A PROJECTION BETWEEN EACH PLANK WIDTH WHEN BOARDING IS REMOVED

Rubbing

Rubbing produces a fine, smooth finish, and the success of this method depends upon carefully judging the right time for carrying it out. The cement and aggregate should have reached approximately equal hardness, or one will be rubbed away before the other ; and tests should be made on small samples before beginning work on the main wall.

Carborundum is usually employed to rub down concrete, but York or Mansfield stone is also suitable. The work is usually carried out by the use of electric surfacing machines, and undertaken by skilled workmen. Concrete will also take a polish if the rubbing is continued, by substituting a fine for a coarse disc on the machine, or using snakestone in the parts where a machine cannot be employed.

Tooling

Precast concrete slabs can also be tooled in the manner of ordinary stone, with a mason's boaster and wide chisel having a serrated edge. It is best to employ this method of finishing the angles of all concrete work, as the mechanical means employed to expose aggregates will probably spall off the material at corners, leaving an unpleasant ragged arris to the building.

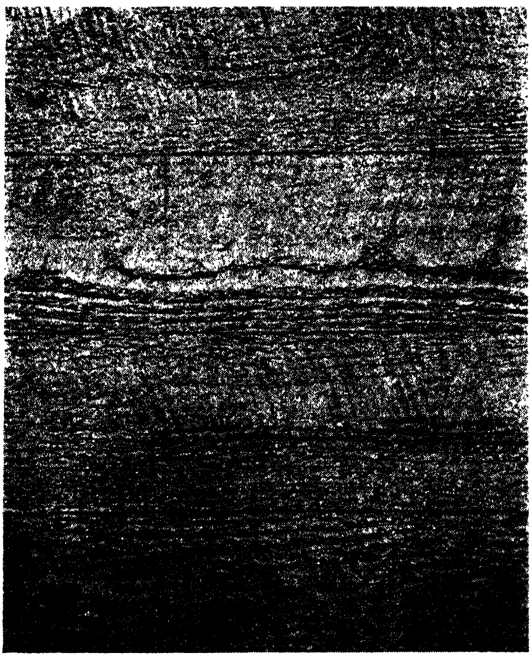
Cement Renderings

One method of finishing the external walls of a concrete building is to treat the concrete itself with a pleasant-coloured wash or slurry, made

up of Portland cement, sand, and water. Naturally the shade will vary according to the mix. Ordinary Portland cement when dry has a greyish and rather drab appearance, but a bright finish can be obtained by employing a white cement. The colour can also be varied by mixing the cement with various shades of sand, so that nearly all tones can be produced from snow white to dark brown without the addition of colouring pigments. But for external work it is best to restrict the colours to cream or white, as darker tints are liable to be disfigured by efflorescence.

Cement Wash

The slurry should first be mixed dry, and then have water added until the mixture is of the consistency of stiff paint. The addition of about 5 per cent. of hydrated lime is sometimes advantageous, as it tends to reduce the harshness of the mix. Only enough of the slurry should be made to last an hour ; the pail should then be cleaned out and a fresh batch prepared. During the application of the slurry to the wall it should be frequently stirred. Provided that the sand is bone dry there is no harm in making up sufficient of the mixture, dry, to last the day's work ; but any dampness in the sand will cause the dry mixture to begin to set, and thus lose its virtue before use.



By courtesy of the Cement & Concrete Assn.

Fig. 6.—Face of concrete after the removal of rough-sawn boards 6 in. wide

The vertical joints are made afterwards. This finish is also a suitable base for "spatter dash."

Method of Use

Before applying the slurry to the face of the wall the cement should first be well wetted, and the mixture then laid on with a full brush. On completion the surface should again be brushed over with water, so as to render the skin as thin as possible, provided that the concrete is everywhere covered.

Rubbing with Carborundum

Rubbing with a carborundum brick improves the surface and makes a better bond by forcing the wash

into the pores of the concrete wall; it also leaves a semi-smooth appearance. In dry weather the wash is liable to dust up if not kept sprinkled with water every twelve hours for two or three days. One method of preventing this dusting is to use a 3 per cent. solution of commercial calcium instead of plain water when preparing the slurry. The calcium attracts moisture from the air, and preserves the dampness of the slurry for several days until the mixture has set. On the other hand, calcium always attracts moisture, and is thus not an altogether desirable ingredient in a wall surface.

Dash Coats

A very effective finish to a wall formed in shuttering composed of square-edged rough timbers, as already described (Fig. 6), is one known as spatter dash. This is a rich cement rendering mixture, containing 1 part of cement to 1½ part of coarse-graded sand mixed in with 1 part of water, all the ingredients being measured by volume. The mixture should be stirred until it becomes the consistency of a thick cream, and then flung on to the wall from the pail with a whisking motion with a bristle brush. Before applying the spatter dash the concrete face should be wetted down, but not soaked with water, as this will destroy the necessary suction required to make the spatter dash adhere. When completed, this facing should be kept damp for about ten days to allow the cement to set. One way to do this is periodically to spray the walls with water through a rose, but another and better method is to hang damp hessian cloth or kraft paper over the face of the wall. This not only keeps the cement damp, but also protects it from wind and rain until it has properly hardened.

Painting and Staining Concrete

A smooth-finished concrete wall can be painted, provided that special precautions are taken to resist the action of alkalis and damp. The painting should be deferred as long as possible, to allow the water to dry out of the mixture, and the first coat to be applied should be some special inert primer made with waterproof and alkali-resisting oils or synthetic resins. Subsequent coats may be of ordinary oil paint, but it is advisable to use tung oil as a base in preference to linseed oil, as it is more resistant to alkalis.

Concrete can also be stained by means of creosote, ferrous sulphate, or copper sulphate. Before applying either of the sulphates the surface should be damped, and as these do not give even colouring it is recommended that they should not be used for large surfaces or important elevations. Another staining mixture is composed of boiled linseed oil and tung oil, thinned with turpentine or naphtha. Any colour pigment can be added to this base, and a large number of shades is possible.

Precast concrete slabs can also be metal sprayed, and afterwards

polished, but the process is not practicable for inside walls *in situ*, and should be confined to small cast ornamental parts which are subsequently built in.

FLOORS

Concrete and reinforced-concrete floors require a finishing to render them suitable for use, and for this purpose a large number of different materials are available, which it is convenient to classify generally as semi-permanent and permanent. We are concerned in the following with the permanent types of floor covering. Under this heading may be mentioned stone, tile, marble, mosaic, and terrazzo, the various types of magnesite composition floors and granolithic floors.

MAGNESITE FLOORING

This may be considered as one of the permanent types of flooring, being a monolithic mixture laid on the concrete and spread in the manner of cement screeding. It is a compound of magnesite, magnesium oxychloride, and different fillers ranging from sawdust to powdered asbestos. Magnesium chloride being very hydroscopic, this type of floor is unsuitable for damp situations, where it is liable to sweat and eventually break up and lift from the concrete base.

Preparation of Ground Concrete

On ground concrete, therefore, a damp-proof bitumen coating should first be spread over the floor, and a further precaution consists of diminishing the proportion of sawdust and substituting an inorganic filler. This may render the floor harder, but will assist it to remain satisfactory in humid surroundings.

Laying Magnesite Flooring

Under normal conditions, magnesite flooring is laid directly on the concrete without a cement screed, in one or two layers (preferably the latter for first-class work), and will set hard in about forty-eight hours.

Ordinary Floors

For ordinary floors the compound should be composed of about 45 per cent. ground magnesite and 55 per cent. wood flour, asbestos, or talc, and chloride of magnesium.

Heavy-duty Floors

Heavy-duty floors can have a slightly different mixture—of about 55 per cent. ground magnesite and 45 per cent. graded hardwood sawdust and chloride of magnesium.

This can be laid in one coat on solid flooring $\frac{1}{2}$ in. to $\frac{3}{4}$ in. thick, but ordinary flooring is best laid in two coats $\frac{3}{8}$ in. thick, the lower layer being composed of 25 per cent. ground magnesite and 75 per cent. sawdust. The bottom layer should be reinforced with wire mesh or light expanded metal to prevent cracking. If the whole floor is not reinforced in this way, on account of expense, strips about 2 ft. wide should be laid over all joists and beams embedded in the concrete, or temperature changes in the steelwork may tend to crack the magnesite flooring above.

Magnesite Flooring Must Not Come in Contact with Ironwork

All ironwork in contact with magnesite flooring should be treated with red lead to prevent corrosion, and where pipes come through floors a sleeve piece should be fitted so that the pipe can be removed without disturbing the floor.

Non-slip Surface

To ensure a non-slip surface, Alundum compound can be worked into the top layer in the proportion of $2\frac{1}{2}$ lb. of Alundum to 1 sq. yd. of finished flooring, the granules being incorporated as the floor is laid to a depth of about $\frac{1}{4}$ in. Magnesite flooring should not be allowed to touch plaster, which may absorb the magnesium chloride and after a time break up and powder away. It is best to divide the two materials by a definite break between walls and floor, which can be done either with a suitable metal strip, a wood skirting, or a Portland cement cove.

These jointless floors are waterproof, dustless, and hygienic and, as they are laid without a cement screed, save cost.

Cleaning Floors

A few special precautions must be taken in cleaning them. Soap or soda should never be used, but if the surface becomes very dirty it should be well scoured over with steel wool or a bunch of steel shavings. When the dirt has been removed the whole surface should be given a rub over with a good linoleum polish diluted with turpentine. Periodical dressings of raw linseed-oil feed the floor and preserve the brightness of the colours.

Dermas Flooring

Another floor composed largely of the same fillers and magnesium chloride has in addition an asphalt emulsion which eliminates the need of feeding the composition with oil from time to time. It also makes a very resilient surface to walk upon.

TERRAZZO FLOOR

Before laying this type of flooring, which is in fact a rough imitation of mosaic, the surface of the sub-floor must be carefully cleaned, soft patches hacked off, and a screed of cement mortar applied. It has

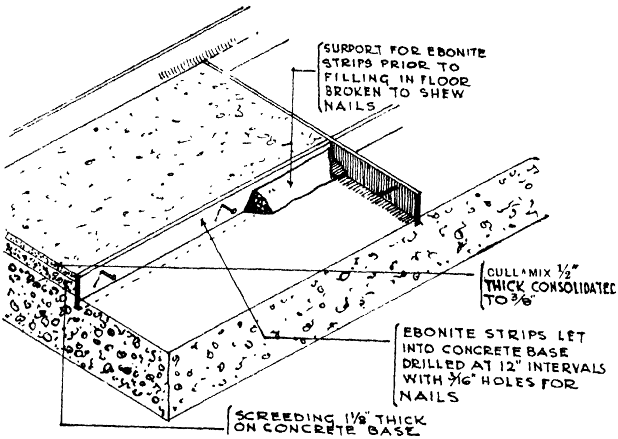


Fig. 7.—PREPARATION OF FLOOR FOR CULLAMIX

been found by experiments at the Building Research Station that the application of a slurry to the subfloor, under the screed, improves the bond. The slurry is composed of neat cement and sand (1 to 1) and is followed immediately by the screeding, composed of 2½ to 3 parts of clean sand to 1 of Portland cement.

When the screed is dry it should be cleaned of dust and wetted to a moderate extent, enough to prevent too great suction when the terrazzo is laid.

Laying

Terrazzo is a compound of crushed marble, aggregate, and cement. Owing to the fact that it is made with a mixture rich in cement, and not well graded according to the ordinary mixing formula, there is often a tendency to crack and shrink after drying. To counteract this tendency terrazzo should be divided into panels with brass or ebonite strips set in the screed. These panels can be arranged to form any desired pattern in the floor but none should have greater superficial area than 20 ft. Even so, the corners tend sometimes to warp and lift; therefore, when laying, special care should be given to the work in these places.

Different Aggregates

Other aggregates that can be employed are crushed coloured enamels and glass mixed with coloured cements, and the natural colours of the marbles can be still further enhanced by employing white cement in which to set them.

Colours for Terrazzo Floors

There is a wide range of colours in terrazzo and all are satisfactory except blue and green. Blue will move in the cement where coloured cement is used, and seep to the surface, while all but the best qualities of green are liable to fade. Black is another difficult tone. The aggregate comes from Belgium and is sold in four different qualities. Second-best is usual for good black flooring, and third-best may be used for

cheaper work. This cheaper type of aggregate has fine white markings, and the resulting floor will be of a grey-black shade. Black terrazzo takes some months to mature and will not have its proper lustre until the salts have worked out. These will form a whitish film on the surface at first, but after six months or so should cease to effloresce, and the floor will become a dead, permanent black.

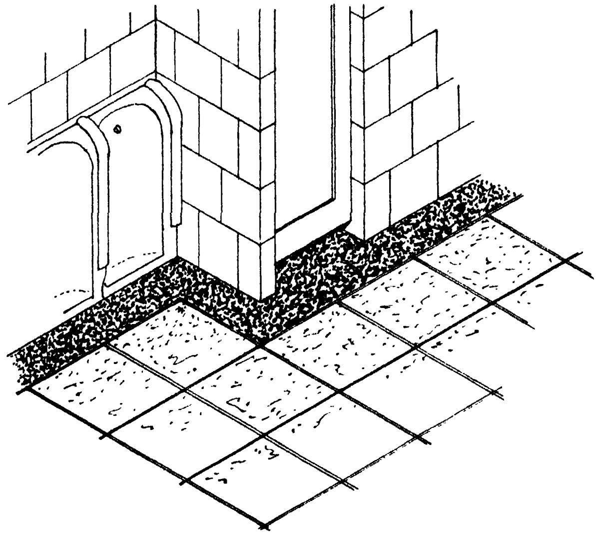


Fig. 8.—CULLAMIX FLOORING WITH BLACK BORDER AND LIGHT-COLOURED PANELS DIVIDED BY EBONITE STRIPS

Setting

Terrazzo should be allowed to set slowly and should be kept moist until hardened, though when laid *in situ* these ideal conditions cannot be complied with, one of the most serious dangers being the testing of the hot-water system (if one exists) before the floor is dry. The uneven setting caused by the heat and draughts may set up strains in the hardening cement which will lead to bad cracking of the floor.

Precast Terrazzo Panels

Precast terrazzo panels about 12 in. square, made in a hydraulic press, will solve this difficulty where speed is important. These tiles are kept in water for several days after manufacture and thus develop the full strength of the cement ; they can then be laid at once and after about twenty-four hours are fit for traffic.

The final process in laying the floor is to clean off and polish by rubbing with a weighted stone and water until a perfectly smooth surface is obtained. Terrazzo when laid is usually given a grit finish, but even so the surface in time may become slippery through several causes, one being the coating of the surface from wax-polished floors, the grease of which is carried on the feet from rooms in an office building to the terrazzo passages. The old method when this occurred was to rub down again with rubbing machines, but modern methods include the use of a solvent which can be employed without skilled workmen.

Cleaning

Soap, of either bar or powdered varieties, should never be used in cleaning a terrazzo floor. Clean, plain water mopped on will remove all dirt, which cannot be ground into the hard surface and will come away readily with elbow-grease.

The Use of Carborundum to Prevent Slipping

Carborundum can be used to prevent slipping on wet terrazzo round swimming-baths or on permanently wet floors, but as the material which is dusted into the aggregate as it is laid acts by sticking slightly up above the general floor surface, it is not very satisfactory for people who are not wearing shoes.

Indented tiles of terrazzo are now made in which the surface is covered with V-shaped grooves that act by suction on the soles of the bathers' feet. These tiles are very hard and will stand up to wear better than ordinary terrazzo laid in the usual way.

CULLAMIX FLOORS AND TILES

This is a terrazzo type of material composed of coloured cement and special aggregate ready mixed for use, the chief characteristic of which is an exposed white aggregate of chips embedded in a matrix of coloured cement, the shade and colour being obtained through the tone of the matrix. This is the reverse of ordinary terrazzo, where the colour is produced by the coloured particles of the aggregate.

Range of Colours

The range of colours in cements used in Cullamix is large, ranging through pink, terra-cotta, brown, violet, black, green, burnt sienna, and yellow to white. Large areas are divided up into separate colours by means of ebonite or brass or bronze strips in the same manner as terrazzo floors.

Preparation of Floor

Before laying Cullamix the concrete floor should be well brushed clean and have a surface sufficiently rough to give a good key. The dividing ebonite or brass strips, $1\frac{1}{2}$ in. deep and $\frac{1}{8}$ in. thick, should be fixed on the concrete about 10 ft. apart, and the strips then drilled with $\frac{3}{16}$-in. holes about $\frac{3}{4}$ in. from the top at 12-in. intervals to allow of 1-in. wire nails being passed through them. The strips are first held in position and dabs of cement mortar pressed against the free side to within $\frac{5}{8}$ in. of the top of the strip. The nails are then inserted from the other side so as to project evenly both sides of the strip, and the mortar is then built up on the other side. The strips should then be left for the mortar to harden sufficiently to hold them firmly in position.

The Screed

The concrete sub-floor should be thoroughly wetted with clean water, and unless it is in a new building a thin slurry of neat cement brushed on to give a key to the screed. The screed and topping of Cullamix is approximately $1\frac{1}{2}$ in. thick, the screed accounting for $1\frac{1}{8}$ in. of this depth, and the topping for $\frac{1}{2}$ in. nominal thickness, but this will be reduced to $\frac{3}{8}$ in. when tamped down and consolidated into the screed. The mix for the screeding should be 4 parts aggregate of clean washed shingle graded from $\frac{3}{8}$ in. down, 2 parts clean sand, and 1 part Portland cement.

The Cullamix in plastic form is laid on this to the required level while the screed is still green, and levelled up by a wood straight-edge, not scraped off but tamped down. A final smoothing is then made with a steel trowel. Just before setting, it should be rolled with a steel roller until the surface cement begins to stick, when this should be removed with a steel trowel with a scraping action.

When dry, the whole surface of the floor is brushed with a wire brush.

Floor Polishing

If the floor is to be dry polished it should be kept damp for two days after laying before being allowed to dry naturally, but if wet polishing is required the floor must be kept damp until this is done.

Wet Polishing

Wet polishing produces a smoother surface and should be done about a week after laying ; the actual time will vary with the temperature and the colour employed in laying the floor. The surface is first rubbed down with carborundum stone until the white aggregate is everywhere exposed, when the rubbing should cease and the floor be washed. If small pittings show after rubbing down, these holes should be filled in with grout mixed to a plastic consistency and worked in with a wooden float. A light sprinkling of cement should then be applied and the floor rubbed over with a soft rag, After a further lapse of 24 hours the final rubbing may be carried out.

Cleaning Cullamix Floors

Acids should never be used in cleaning Cullamix floors, and an effective means of preventing staining by oil is to treat the surface with paraffin wax dissolved in petrol and applied with a rag.

Cullamix Tiles

Cullamix can also be laid in the form of tiles. Each tile is made under pressure and is true to shape, and provided with a keyed back ready for laying. Before being sent out they are polished with wax and when laid can be kept in good condition by an occasional application of wax polish.

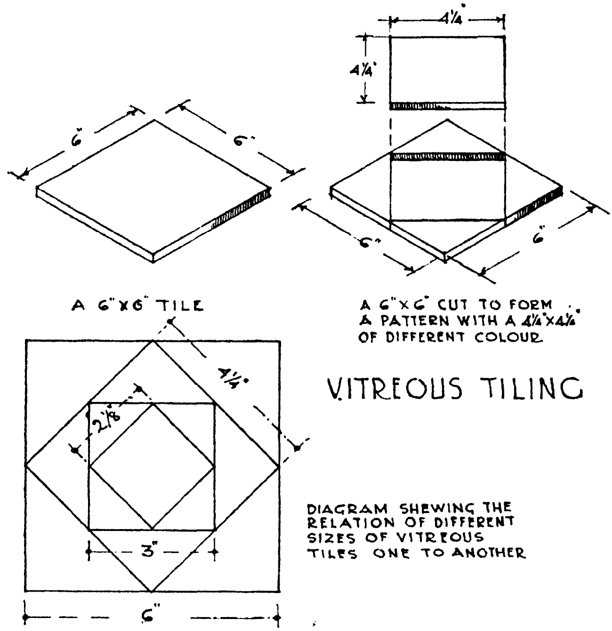


Fig. 9.—SIZES OF VITREOUS TILING

The tiles are made in 6-in. by 9-in. squares, and are fireproof, non-crazing, fadeless, and lighter in weight than quarry tiles. They can also be cut in the same way as glazed tiles.

Cullamix floors are suitable for hard wear in such places as industrial buildings, canteens, and factories and power houses on account of the freedom from dust.

ASPHALT

This material, which is a form of natural bitumen, is either laid as a powder compressed by rubbing with a hot iron or, more usually in building work, heated in cauldrons and applied hot as a mastic.

The best-known source of the former is the Pitch Lake in the island of Trinidad, and of the latter the Val de Travers in Switzerland, which supplies what is really a bituminous limestone.

A plain asphalt floor from ½ in. to 1¼ in. in thickness need not, in many cases, be covered with any other material. If it is carried up the walls and finished with a coved skirting, such a floor will take a good polish and makes a pleasing blackish base for coloured rugs. But in laying the material the concrete floor must have an absolutely dry surface to get proper adhesion, and fine ashes are sometimes brushed over the surface immediately before laying.

Colorphalte

Colorphalte is a rock asphalt fluxed with Trinidad Lake asphalt, and has colouring pigments added. It can be laid as ordinary asphalt, already described, in a mastic state; or in tiles already hardened and coloured. Where dustless floors are essential, or where salt or sea water is present, asphalt forms an excellent flooring material; and in chemical works and laboratories, where corrosive acids are likely to be spilt, the best type of floor is one laid with acid-resisting asphalt.

MOSAIC FLOORS

These floors are made of tesseræ or small cubes of sanded glass, burnt clay, or marble. In the best work it is usually set piece by piece in the prepared cement bed, but a cheaper commercial method is to fix the cubes face downward on paper with an adhesive. The patterns thus made up at the works are transferred to the cement grout on the job, and when dry the paper is washed off. A final operation is to run liquid cement into the spaces between the cubes.

Marble cubes wear the best as a mosaic floor; burnt clay has a tendency to become slippery in time and should have a non-slip material mixed with it. Glass mosaic has a rougher surface owing to silica in the composition, but sometimes has a tendency to "dust up" under heavy wear. Vitreous mosaic is more suitable for flooring than glass.

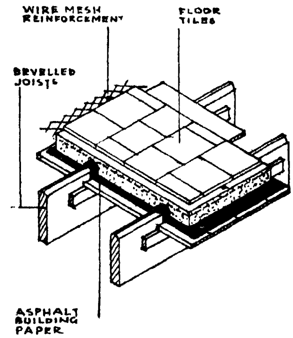


Fig. 10.—TILE AND CONCRETE FLOOR LAID ON BOARDING AND ASPHALT PAPER

Note that the concrete is reinforced with wire mesh and the top edge of the joists bevelled. The underboards are supported on fillets.

Cement Mix for Mosaic Floors

The mix of the cement used is important, and one of the best is composed of Leighton Buzzard sand and "Snowcrete." The finished thickness of a mosaic varies, but is never more than ¾ in. above the concrete —including the cement and sand bed on which it is laid.

MARBLE AND STONE PAVING

To lay these floors, the screeding under the slabs must be carefully levelled as the slabs are liable to crack if unevenly bedded. Marble flooring is often bedded in a mixture of stone dust and lime known as Parian cement, but the majority of marbles are not suitable for heavy wear, and cannot be obtained in large slabs. Failure of floors is sometimes caused through choosing marbles of different wearing capacities and laying them together when making up the design, and it should be remembered that green and black tones are usually harder than white. The same danger is present when a mixed stone and marble floor is laid, and the abrasive properties of the various materials should always be ascertained in such circumstances.

Laying a Marble Floor

In laying a marble floor, about ½ in. of screeding is first laid over the whole of the concrete, made up of sand and Portland cement. The screed should be finished below the floor level a distance equal to the thickness of the tile plus ¾ in.; that is to say, if the marble is ¾ in. thick, the screeded floor should be 1½ in. below the finished floor level. The composition

cement for laying marble should be very dry and made up in a proportion of 8 to 1 ; at least three days should be allowed for the floor slabs to set, and no heavy traffic should be permitted before the end of fourteen days at the earliest.

Washing powders often contain caustic alkali and should never be used on marble floors ; a similar prohibition must also be exercised over all powders containing fats, as these will render the floor slippery when dry. Marble is always a dangerous floor, and should never be polished to a higher degree than a grit finish if it is to take any considerable amount of traffic.

A Simple Method of Making Marble Surface Non-slippery

The Building Research Station has suggested a simple method of making safe a surface which has worn slippery. They suggest a compound of sawdust and hydrochloric acid in the proportion of 16 oz. of commercial acid to 1 gallon of water. This is mixed with sawdust until it forms a sloppy paste, which is then spread over the marble to a thickness of about 1 in. and left for fifteen minutes. On removal the floor is washed two or three times with clean water, when the surface should be safe to walk upon, and no discoloration of the marbles will have occurred.

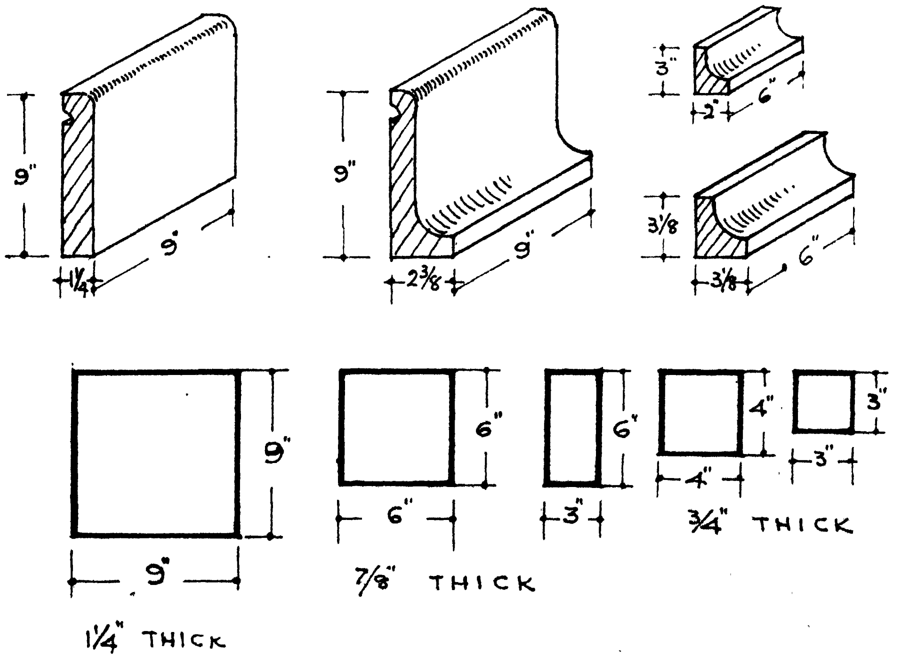


Fig. 11.—General sizes of terra-cotta and quarry tiling, with skirting and coving tiles

TILES

Usual tiles employed in flooring may be classified into Terra-cotta, Quarry, Tessellated, and Vitreous.

Terra-cotta

Terra-cotta tiles are made from clays, found in various parts of England, which contain a large percentage of silica. The red colour common to terra-cotta paving is usually caused by the presence of oxide of iron. The tiles can be obtained in a variety of sizes and are best laid with the specially made skirting or coved angles supplied by the makers. Such flooring is smooth, clean, and strong enough to stand up to ordinary wear and tear. Various sizes of terra-cotta tiles are manufactured in different thicknesses, and it is well to select sizes having the same depth, to simplify the level of the screeding below.

Quarry Tiles

Quarry tiles are usually of a large size: 9 in. by 9 in. or 12 in. by 12 in., though smaller sizes are obtainable. They are composed of a coarse clay which, when broken, shows in section a fine skin over a rougher interior. They are suitable for ordinary wear and general domestic use in sculleries, wash-houses, etc., but will not stand up to heavy traffic, having a tendency to powder and disintegrate when the skin is broken through.

Tessellated and Vitreous Tiles

Tessellated and vitreous tiles are similar in general appearance, but the latter are fired at a higher temperature and are composed of a slightly different clay containing a higher percentage of felspar; they are therefore harder. Both these types of tile are made under pressure and are burnt well, so that when broken they show the same consistency throughout the tile.

Sizes of Vitreous Tiling

The usual size for vitreous tiling is 3 in. by 3 in. and smaller. These dimensions ensure the tile not twisting when fired, but sizes of $4\frac{1}{4}$ in. by $4\frac{1}{4}$ in. are possible, or even larger, though owing to the rejections from the kilns of these larger sizes the cost rises sharply. The common sizes for tessellated tiling are 6 in. by 6 in. and divisions of this size. The most usual are 6 in. by 6 in., $4\frac{1}{4}$ in. by $4\frac{1}{4}$ in. (this being exactly half the area of 6 in. by 6 in.), 3 in. by 3 in., and smaller. The common thickness is $\frac{1}{2}$ in., but $\frac{5}{8}$ in. is made in certain colours.

Laying the Floor

To lay the floor, it is first screeded to $\frac{5}{8}$-in. thickness; the tiles are then set in $\frac{1}{4}$ in. of cement and sand and well beaten into the material. Joints

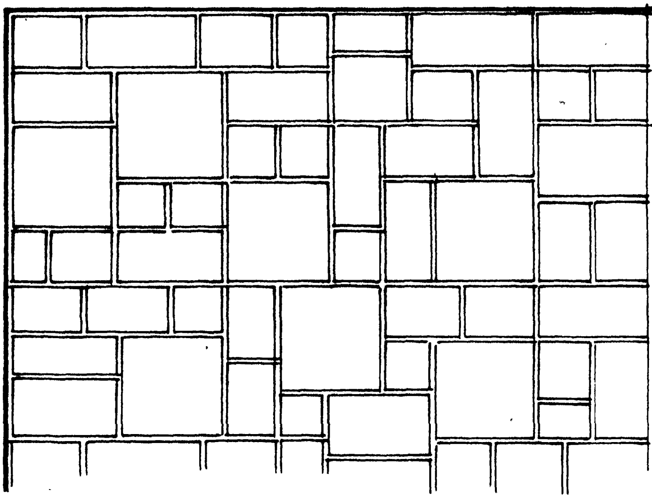


Fig. 12.—Random quarry-tile flooring, using 9 in. by 9 in. as the largest unit

are grouted in with cement and sand and the surface cleaned off. Over large areas a bituminous surround is sometimes put to obviate cracking should movement take place in the building. Acid-resisting floors and floors of dairies, where there is danger from lactic acid, are frequently laid with vitreous tiling having the joints filled in with super cement or bitumen ; in the latter case great care must be taken to prevent staining the tile surface.

The colours of tessellated and vitreous tiling are fast, but brilliant tints are impossible and designs incorporating bright greens or reds cannot be carried out.

Ratio of Sizes

In designing a floor the architect should notice the special relation between the 6-in. by 6-in. tiles and the 4¼-in. by 4¼-in. already mentioned, the latter fitting diagonally exactly into the space of the former, the angles touching the centre of each side. The 3-in. by 3-in. again fits into the 4¼-in. by 4¼-in. ; and a smaller tile, made 2⅛-in. by 2⅛ in., again fits diagonally into the 3-in. by 3-in. By using these sizes, and by cutting the tiles, a variety of designs can be carried out without waste.

Tiling on Wood Joists

Where necessity demands, and over small areas, it is possible to lay solid floor tiling on wood joists. A good method is as follows. Between the joists at a convenient level nail battens, and on this fix boarding, at the same time rounding off the upper edges of the joists to be covered. Over the whole lay waterproof asphalt paper and pour in the concrete, which should be reinforced with some type of expanded metal. When the concrete has set the tiles can be laid as on an ordinary concrete floor. Care must be taken to ensure that the joists so covered are thick enough

to take the extra weight without deflecting, and in any case there is always the danger that the surface may crack through movement. The better method is always to remove the joists where possible, and replace with a reinforced-concrete or hollow-block floor.

GRANOLITHIC FLOORS

These are concrete floors rendered suitable for heavy wear by the use of an aggregate largely composed of granite chippings. If a granolithic floor is not laid with care it is liable to dust up. Various causes produce this trouble, but the most common faults are improper mixing of the materials or over-trowelling of the final surface, which brings the small-size portions of the aggregate to the surface.

Mix for Granolithic Floors

The Cement Marketing Board suggest that the mix for granolithic floors should be composed of 1 part Portland cement by measure, ½ part fine aggregate, and 2 parts of coarse aggregate; another good volume measure is 1 cwt. Portland cement, 2 cub. ft. of sand, and 5 cub. ft. of granite chippings small enough to pass a ⅜-in. mesh. The topping coat is 1 in. thick, and composed of Portland cement and granite chippings in the proportion of 2 to 5. The granite chippings should be free from dust, and able to pass a ¼-in.-square mesh.

Methods of Laying

There are two methods usually employed in laying a granolithic floor. In the first, the base layer is spread to the depth required, which may be 3 in. or 4 in., on a bottom of hard core. This base layer is brought to a level 1 in. below the finished floor line by means of a straight-edge. The excess water is then removed from the surface, and after being allowed to stand for about two hours the topping coat is added and brought up to the finished level. Two or three hours later the surface should be gone over with a steel float before the cement takes the final set.

As new granolithic flooring cannot be used for about five days after laying, and must be protected, this method may considerably hinder the progress of the work. Even when the floor is set it is liable to be damaged by scratching and wear of workmen passing to and fro before it has attained sufficient hardness.

The second method causes no delay, as the base is laid and left to set like ordinary concrete, and slight damage does not harm it. Careful preparation is required at a later stage, when the topping is to be added, to ensure a proper bond between the two layers. The base should first be washed clean and then thoroughly soaked with water. A mixture of cement and water, of the consistency of thick cream, should then be vigorously brushed on the wet surface, and before this grout has had time

Fig. 13.—Laying a granolithic floor (1)

Laying the topping on the base layer. After throwing the granolithic with a spade it is roughly smoothed with a float. Notice the straight-edge supported on the dividing face-boards.

Fig. 14.—Laying a granolithic floor (2)

The straight-edge is pulled towards the workman with a slight tamping action, to produce the level granolithic surface.

Fig. 15.—LAYING A GRANOLITHIC FLOOR (3)

Filling in the joints in the finished floor after removing the facing-boards between the bays. The straight-edge can be seen on the right.

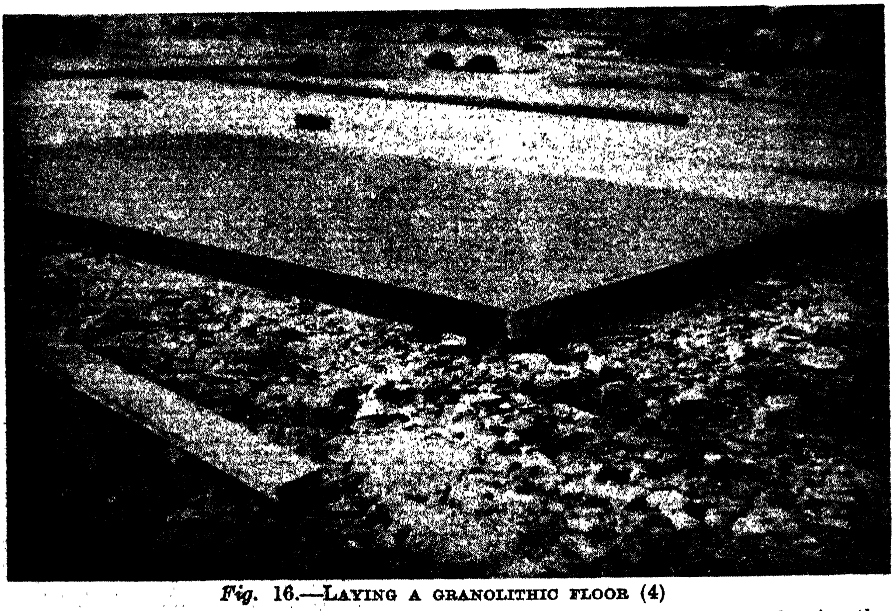


Fig. 16.—LAYING A GRANOLITHIC FLOOR (4)

Portion of the finished floor, the facing-board removed at external edge, showing the hard-core bottom of broken brick, and the lower and upper layers of granolithic.

to set the topping coat should be spread and brought to a smooth surface. It is then finished, as before described, with a steel float.

The floor must be protected from weather for at least twelve hours, and care taken to prevent too rapid drying in wind or sun. It is a good practice to keep the floor damp for at least ten days after laying, to obtain the hardest possible surface and freedom from dust.

Precautions in Laying

To prevent cracking due to expansion and contraction the floor should be laid in areas not exceeding 40 to 50 superficial feet. This is done by dividing the area to be covered into rectangular shapes with facing-boards. These boards are trued up and used as gauges for the straight-edges, which rest on them for the purpose of smoothing out the surface.

On completion of the work these boards are lifted out and the spaces filled in. Another way of preventing cracking is to cover the base course with steel-mesh fabric, so that it acts as a reinforcement to the topping.

To prevent slipping, carborundum may be sprinkled on to the topping coat, but the use of driers, such as neat cement and sand, is not recommended as they tend to make the floor dusty. Another method, to gain a good foothold in yards and garages, is to roll the topping coat with a pinhead roller before it has finally set.

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